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PROCEEDINGS

OF THE

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

VOLUME 46

1930

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GENERAL INDEX

INDUSTRIAL POWER FROM THE STANDPOINT OF THE EXECUTIVE*

By J. C. Hobbs†

This paper will deal, first with the general relationship of industrial power to modern civilization; second, and more specifically, with some of the underlying principles of industrial power; and third, with a few practical suggestions of an executive nature.

American success is due to the adoption of the Grecian slave policy. Long ago, the Greeks and others believed that slaves were necessary to the progress of civilization. They realized that the energy exerted by one man was not sufficient to provide all the food, raiment, shelter and other bare necessities of life, and at the same time provide for luxuries and the creation of public improvements, so with mathematical precision they determined the sum total of all the energy existing, and proceeded so to direct and control the activities of certain classes that their requirements were reduced so that a few could enjoy the benefits due to the appropriation of the excess energies of their slaves.

America is doing the same thing to-day. Every man, woman and child in the United States has on the average about fifty faithful slaves working steadily eight hours a day, 365 days a year, besides the 300 slaves required to pull the family chariot; and, furthermore, these slaves can be bought and maintained more cheaply than the Greek slaves, the average being less than two cents a day. America, more than any other great country of the world, realizes that the more slaves she uses, the greater will be her production, her progress, and her prosperity.

During the past twenty years, the number of slaves has more than doubled every five years. It is needless to explain to you, who are interested in power, that the electrical and mechanical robots now employed in America are more satisfactory in every respect than the ancient type.

The history of power as an important factor is not old. A good bird's-eye view is obtained by merely counting the pages required to record the major discoveries and inventions.‡ Ludwig Darmstaedter's

*Presented October 1, 1929. Received for publication January 9, 1930.
†Superintendent of Power, Diamond Alkali Co., Painesville, Ohio.
‡*Outlook and Independent*, v. 152, p. 325.

"Handbuch zur Geschichte der Naturwissenschaften und der Technik"* uses only two pages each for the eleventh and twelfth centuries; five for the thirteenth, four for the fourteenth, 10 for the fifteenth, 33 for the sixteenth, 55 for the seventeenth, 117 for the eighteenth, and 717 for the nineteenth. Libraries will be required for the twentieth.

The rapid increase reminds one of the history of electrical power, all of which is within the memory of this audience. In a magic manner, the growth has practically doubled every five years during the last four decades. Of course, this law can not be followed much longer, but the enormous size of even the utility division to-day would not have been predicted 20 years ago.

So much for past generalities. To-day industrial executives are confronted with many problems of production, all of which are linked with the use and application of power no longer a minor factor.

Power, although invisible and intangible, is one of the major elements in the manufacturing and marketing of most industries; and, as such, deserves the same scrutiny and careful analysis as any other of the prime elements or materials used in the processes. Some industries owe their very existence to low-cost power.

The phrase, "cheap power," is not used here because, fortunately, the quality of power is always close to perfection, and the measure so uniformly correct as to be suggested by a leading industrialist as a better standard of exchange than the United States gold dollar, so why use a term with a double meaning which might cast a doubtful reflection on its noble character. This address deals not with the old controversial subject of central station versus isolated plant because there is but one true answer to each case, and that must be derived from the facts in each case.

It is unfortunate if there are still those who, for the sake of proving or supporting some previously made proclamation, will knowingly use their influence to prevent the adoption of the proper solution of any power problem. Certainly they do not recognize the fundamental law that any contract to be of lasting good must be fundamentally sound, and that foreign competition requires, if not compels, the adoption of the most economic methods.

*Julius Springer, Berlin, 1908.

Some foreign countries have already removed their own internal handicaps of competition by organizing co-operative agencies through which an exchange of progressive methods is made. The public has never realized the great debt it owes to the co-operative committees of the National Electric Light Association, which have been so largely responsible for the rapid growth of the electrical industry, yielding benefits and blessings to all mankind. Particular credit is due the technical committees, and it is a pleasure to call attention to the fact that a modest Pittsburgher, Mr. E. C. Stone, has been National Chairman of these committees during the past year. The leading manufacturers of power equipment also deserve credit for their research work and their co-operation in developing improved apparatus.

Wrong power policies are indorsements of waste—the greatest factor in every industry to-day. Waste is occurring in so many forms that it is always a fertile field in which to find fortunes, so why encourage the thing which is the very enemy of prosperity.

The basis of attacking the problem of purchasing or making power should be that the interests of industry and of the owner of the utility are one and the same. With such a fundamentally sound basis, the best method of operation should first be determined, after which the cost analysis should be made, to be sure that both parties will benefit. If not, then the problem becomes one not of power or heat engineering, but of commercial and financial engineering, which is just as important as the former. Sometimes the rate schedules are such that a profitable relationship is absolutely prevented; then again, certain dyed-in-the-wool prejudices will crop out on one side or the other and become an obstruction to prevent early realization of possible benefits.

Broadly speaking, the trend appears very plainly to be towards the co-ordination of all sources of power generation into one system. Most of the power will be generated in central condensing stations, but an increasing amount though a decreasing percentage of the total will be produced as a product of certain industries. The central-station utility is the logical agency to distribute all power. It is realized that some of the large utilities have not adopted this policy, but the success obtained by other progressive utilities and the growing number of such interconnections, together with the soundness of the policy, argue well for its future adoption.

The executive is continually confronted with costs in his endeavor to produce some article or service for which the public can pay, but in some cases is willing to pay only an amount slightly in excess of the cost.

The wise manager realizes that reducing costs will reduce the selling price and broaden the market so he can make more, reduce the cost further, and sell more, and so on, to the end that more profit will be obtained.

The most valuable tool the manager has with which to lower expenses is an accurate cost record. This is, however, rarely available, due to arbitrary and sometimes biased accounting. Such records are needed in order to see that the trend is in the right direction and that progress is being made. Without clear-cut dependable figures, intelligent decisions can not be made in connection with future policies. This point is well illustrated by the fact that no single figure can represent the cost of industrial power. Perhaps this is not recognized, so a more detailed explanation will be made, using an independent industrial electric station as an example in which there may be as many as four true costs for electric power.

1. The total cost of power, including fixed charges on all equipment used in any way for the production of power as a primary product without taking any credit for by-products.

2. The book charge which may be made for power when it is generated as a co-product, and the value of the advantages obtained by combining power and process operations has been divided equally or in some fair manner by the co-operating operations.

3. The actual net cost of power consisting of the fixed charges on the total additional investment required in order to produce power, together with the total additional operating costs added because power production has been added to the manufacturing operation.

4. The price which can be paid for purchased power without reducing the net profits of the company.

Of the four costs mentioned above, the first is the highest and is the one once used in the days when exhaust steam was considered to cost nothing, so it was good business to sell it for little or nothing, leaving the electric power to carry the whole burden. This is the true cost only when, for certain periods, the exhaust steam is not profit-

ably utilized as is the case with non-condensing operation in the summer when there are no heating or process requirements.

The second cost, defined under 2, is an arbitrary figure used whenever a good heat balance is maintained, and the cost burdens and benefits are shared by the heating and power operations. Attention may here be called to the less usual case in which the heating is done first, and the power production performed later in the cycle. The share-and-share-alike method of distributing the benefits of co-ordinating the operations has much to recommend it.

The third cost is the actual net cost of producing power. It consists of the sum of the fixed charges on all investments made because of power production, and the *additional* operating expense required to generate the power. These operating expenses should not include either operating expenses or fixed charges which would be necessary to distribute purchased power.

The total cost of power (referred to under 4, above) which should be used to compare with a proposal to purchase power to replace power being generated is only that amount which would be saved by ceasing to generate, no allowance being made for fixed charges on equipment which must be disposed of or discontinued. The sum total of all actual reductions is all that can be allowed.

Unfortunately, there have been cases in which a very large investment has been made in isolated plants when purchased power should have been used. When once installed, the owners are condemned to operate these plants throughout their useful life.

If power in addition to that being generated is being considered, then to the former sum must be added an amount equal to the additional operating costs, including fixed charges on additions which must be made. This figure is lower than the other costs, but it is the figure which will show up in the treasurer's bank balance.

In connection with this paper your committee requested a discussion of the relative value of high-grade and low-grade operators.

Poor personnel and unsatisfactory operating methods are usually responsible for increasing operating costs more than can be saved by increasing the plant investment the 25 per cent. required to obtain the last 10 per cent. in efficiency. This is certainly a bad condition and, strange to say, it is seldom recognized because of the old-time impression that a power-plant is a dirty place and only low-grade men can be employed.

Forgetting past habits, it is well worth while to analyze all the conditions, and determine the value of more economical and reliable service, just as investment in equipment should always be scrutinized to make sure that the last per cent. of efficiency or reliability is justified. The most economical type of labor should be selected by the same method. The increased amount paid to an employee can never be allowed to equal the savings he makes in the other operating expenses, without increasing the total costs. On some standardized operations, only the lowest rates may be justified on this basis, but, for every job which affects the larger operating costs, good men are usually well justified. The same method applies to the personnel problem except that usually the value of different classes of men is not so easily determined. Experience has shown that there is usually a big opportunity to reduce costs by utilizing better trained operators. This does not mean wholesale firing and hiring of men, but rather a combined sorting and educational process. The latter involves a detailed and accurate study of all the operations, and the establishing of standards of operation and performance. The power department then becomes a modern well-organized unit. Costs and trends must be indicated to all those responsible for their reduction. This does not mean that each and every employee must be given the complete financial statement, but each one should have indicated to him the results of his efforts in order that he may work intelligently and in order that an intense interest may be sustained.

How much enthusiasm and pep could be secured in a football team if the score were kept secret except to the president of the institution, and perhaps a few of his trusted staff? How long would a bank last if accounts were never balanced and the exact records of each employee made known to him? Why is it that most industries are "penny wise and pound foolish"? Every cent of petty cash must always be accounted for by a respected employee working under good conditions, while the handling of millions of pounds of coal is usually assigned to almost anyone who will take the job. Educational qualifications are not usually examined. Why is it? The answer to this question is the introduction to a new source of profit.

There is no foundation for the old-time accepted impression of power generation. Comparisons with other manufacturing operations will establish this contention beyond a doubt. What product is

cleaner, requires less to pack, check and ship than kilowatt-hours or pounds of steam? What good reasons can be advanced for not having clean, comfortable, well lighted working quarters which will attract intelligent men with good educations? In what other business has an employee the opportunity to handle such large values and increase the profits so much?

When making an improvement in personnel, it is usually worth while to obtain a few well trained men for those operations where the losses suffered during an educational period would be too great, and then train all the others so they can help themselves by helping you.

In large operations, a separate technical department is invaluable for determining facts, maintaining meters, and doing special research work for which operators have neither the time nor the qualifications.

Time is too short to permit more than mention of many important details of which the following are typical:

1. Have written orders for repairs.

2. Have written reports of operation, accidents, and service faults.

3. Have written instructions for operating.

4. Have written routine inspections.

5. Keep the operators informed regarding the reasons underlying various operations. Do not expect them to do anything against their judgment based on their previous experience. As an illustration, most old-time engineers, and many of the new ones, would consider it very bad practice to turn steam into a large line rapidly. As a matter of fact, if the steam is turned into a large line slowly, the chances are about 100 to 1 that the line will be broken because the steam being lighter than the air will float to the top of the line, expanding it while the bottom of the line is still cold. Such failures are bound to occur if the air is not driven out of the line quickly so that the bottom and the top expand at about the same time. One company goes to the trouble of connecting a vacuum pump to the line and exhausting most of the air before any steam is admitted. This is not necessary if ample drains and air vents are provided at the extreme end of the line. This does not mean that any appreciable pressure must be raised on the line because this is not desirable, but it does mean that the steam should be

admitted fast enough so that the air is pushed out of the line ahead of the steam which weighs only half as much as the air.

6. Eliminate the causes of costs rather than only repair the result of wrecks.

7. Simplify.

8. Place responsibility definitely, and respect the lines of authority. Establish responsibility for each operation and judge by the costs, quality of service, and condition of property.

9. Have regular staff and committee meetings with written minutes and a follow up on each item.

10. Keep before the operator a record in chart or tabular form showing the value of the wastes rather than percentages which are more difficult to interpret and evaluate. A loss of $1000 is more impressive, and gets more action, than a figure of 99 per cent. (really a comforting figure) on a $100,000 item.

11. Have accurate records, if feasible. Meter every important item, if you can, and make use of even such crude units as wheelbarrows or buckets. Attention given to any item usually reduces its cost.

12. Use vertical performance and cost tabulations and charts to record all trends. Records are of most value while being made, but they serve also as history.

13. Reward the operators, and always have some incentive in the form of promotion, pride, or the joy of winning in competition in order to obtain their continued interest and loyalty.

It is believed that the same successful principles which have been proved in manufacturing industries can be used with benefit in the production of industrial power, and certainly the same sound methods by which the gigantic electric industry has been created are applicable by the executive in other branches of manufacturing.

DISCUSSION

W. N. FLANAGAN, *Chairman:** The subject is now before you for discussion. I was very much interested in the comparative results of the use of high-grade labor and of low-grade labor. That is apparently all very simple, but the solution is not as simple as it looks. The greatest problem of the industrial power-house from a management standpoint is the question of labor. The first decision that must be made is "shall high-grade operators or low-priced operators be employed?" Both kinds are being used by various successful concerns.

The problem consists of (1) evaluating the high-grade labor without long periods of testing, and of (2) working such a class of operators into a standardized organization.

The first part of the problem is easily considered. For example, let us use an industrial boiler house of about 10,000 horse-power for which we will assume a yearly fuel cost of about $422,000 a year when operated by mediocre firemen. Three men each turn, or nine men a day, at about 50 cents an hour, would operate the stokers and handle annually coal worth $422,000 for wages amounting to $11,140. In other words, each of these men spends, far more directly than the purchasing agent who bought the coal, $47,000 a year.

We may say, double the hourly rate and get higher efficiency by better operators at an additional yearly pay-roll of $11,140 a year; $\$11,140 \div \$422,000 = 2.65$ per cent. This means that the nine higher-grade men would have to increase the efficiency only 2.65 per cent., or a raise from 68 to 70 per cent.

This seems very simple of accomplishment in an average plant, but doubling the wages of stoker operators does not necessarily suffice. There will be about twice that many men in the boiler house proper who will want their pay doubled, also. This would require an increase in boiler-house efficiency of five per cent., or a change from 68 to 73 per cent. This is still within reasonable expectation to make the change worth while to the management. However, in the average industrial plant the power-house is a small percentage of the total labor force which considers itself closely on a par with at least a majority of the boiler-house personnel; therefore, unless the change to the proper kind of power-house employees is made in a very judicious manner, it might cause dissatisfaction among hundreds or even thou-

*Special Engineer, Carnegie Steel Co., Pittsburgh.

sands of other workers, though these workers do not have the responsibility for the direct wastage of such large sums as the boiler-house man.

It will thus be seen that the industrial executive has a far more weighty problem in this respect than a concern whose sole output is power, and this accounts for the seemingly lower efficiencies and poorer labor sometimes encountered in industrial power-plants.

F. M. VAN DEVENTER:* Your example of saving money through increased efficiency by doubling the wages of the laboring man is interesting; but it does not seem to me that this is the most satisfactory method of effecting an operating saving. It would seem more logical to put a good superintendent in charge of the plant and let him spend four or five thousand dollars for good recording instruments, which will work 24 hours a day, and give him a complete check on what the men on *all* shifts are doing. If the superintendent is a good leader, he can use unskilled men at moderate wages, and by demonstrating proper methods of operation and by illustrating each man's improvement from time to time by reference to the operating charts, he can obtain continuous skillful operation.

W. N. FLANAGAN, *Chairman:* That is another method by means of which solution of the problem may be attempted. What I was trying to bring out in the way of management difficulties was the fact that in the industrial establishment there are so many varied employees and if high-grade labor or supervision is suddenly installed in one department, all of the other workers in the same plant might demand higher rates. The same is true in case of bonuses in the power-house. As a relic of the days of small units and hand firing, all the other industrial employees look upon the power-house men, particularly the boiler-house force, as semi-skilled labor despite the frequently greater opportunity for continuous wastage. Mr. Van Deventer's point is well taken. That is a possible means that may be employed with the minimum of dissatisfaction.

To me this is the most interesting phase of management, because, due to the engineer's achievements in the power-house, it is fairly easy to evaluate what you are going to receive in return for changes you

*Mechanical Engineer, H. L. Doherty & Co., New York.

make in equipment; but, when a man has an industrial power-plant to operate, the big problem is the labor problem. It is the one on which he really has the least information.

J. H. Lawrence:* There is one thing that has not been mentioned which seems to me more important than the question of increased efficiency, in order to justify paying higher labor rates. That is the question of keeping the plant going at reasonable cost. There is no place around an industrial plant where men can do more harm in a few seconds than in a power-house. A turbine of even 5000 kilowatts capacity represents an investment, with condenser and other appurtenances, of somewhere between $100,000 and $200,000.

If an operator is careless, he can very quickly make scrap out of the whole investment. I think this is one point which is very generally disregarded. The owner will spend a lot of money, in some industrial plants into the millions, just for the power installation, and an investment of $100,000 or $200,000 is common. You would think that after making such an investment, thought would be given to the men in charge of such a power-house. However, you generally find that second-rate men are put in charge of the power-plant, because the owner does not pay sufficient attention to this end of his business.

I can remember one case where a manufacturer invested about $500,000 in a power-plant and in a year the plant was almost a complete wreck. If some one had not taken over the operation of the plant, it is doubtful if it would have lasted six months more. The reason a good man was not put in charge in the first place was because it would have meant paying a good salary to the chief engineer of the plant, and this salary was more than was being paid in the industrial part of the works. They finally had to pay a good salary in order to get a man who could operate the plant in a satisfactory manner, but the damage which had already been done would have paid this man's salary for many years.

There is so much money involved and the value of the fuel burned is so considerable that it is not good policy to put a second-rate man in charge. It is not necessary that all the employees be of a high type, but at least the man in charge on each shift should know his duties, and be properly educated to take care of the equipment.

*President, Thomas E. Murray, Inc., New York.

I know of one case where no change was made in the personnel of the power-plant and no salaries were raised, with the exception that an engineer from the general office spent part of each day in the boiler room or turbine room instructing the employees in the handling of the equipment. Prior to his arrival the plant was in horrible shape, but at the end of six months he had educated the men so that it was no longer necessary for him to spend his time at the plant. Not only was the equipment kept in proper condition, but the efficiency of the plant was improved considerably. The workmen were intelligent, but they had never had proper instruction in the care of such equipment.

Without proper supervision, it is impossible to expect satisfactory operation. While equipment may be satisfactory when it is installed, if it is not followed up regularly, it will be found that the equipment will not function when it is expected to. We very often find that automatic equipment fails in times of emergency because it has not been given the proper care. The trouble generally is that competent supervision is not supplied until something happens.

J. A. HUNTER:* The remarks have been very much to the point and have brought out valuable discussions on organization, rates of pay, etc.

In central-station work, practically the entire organization is engaged in the production of power; whereas, in industrial plants, the number of men so engaged is a relatively small proportion of the plant organization. The central-station man, therefore, can change the rates of the men engaged in producing power without giving much consideration to the rest of his organization; whereas, if the rates of the men engaged in power production in industrial plants are changed, it may disturb the entire rate structure of the plant.

I believe that the suggestion of Mr. Van Deventer—to have a competent man supervise operation—will produce the desired results without possible difficulties with the rest of the plant organization.

F. M. VAN DEVENTER: Mr. Hobbs has treated the subject from the viewpoint of a large manufacturing concern which is well justified in having a capable power engineer on its staff; but there are literally thousands of small industrial plants using steam and power in

*Assistant Chief Engineer, American Sheet and Tin Plate Co., Pittsburgh.

such small quantities that they are not justified in having a competent engineer on the pay-roll. Usually such equipment as is required in these plants is operated and maintained by a master mechanic who often adopts the ill-fitting title "plant engineer." While such men can keep an account of coal used, etc., they have no knowledge of economics or even of elementary thermodynamics, and therefore are not competent to advise their executives concerning power problems.

The executives themselves seldom have engineering training, and usually their attitude toward their power equipment is anything but cordial, since failures in this department probably have caused costly plant shut-downs.

In a large number of cases the question of rehabilitation is initiated by an equipment salesman, who points out to the plant owner that a considerable amount of money may be saved by the purchase and installation of his equipment. In most cases the indicated saving is based upon bare operating costs, and such an analysis can be made to look very attractive, while a complete consideration of all the facts might show an actual loss by following the advice given. The real need in such cases is an unbiased analysis of the situation by a competent engineer who can determine whether the proposed or some other form of rehabilitation is the better method of procedure, or possibly that the existing source of power and steam, though not modern, may be adequate and more economical than any rehabilitation requiring additional capital outlay. Probably the best method of alleviating this situation would be to urge the various industrial trade journals, which would reach practically every plant owner, to point out the importance of a complete survey and analysis of power situations by a competent and reliable consulting engineer before determining upon any action.

J. C. Hobbs: Thanks are due Mr. Lawrence, who has so well illustrated certain points.

Mr. Skinkle suggests to me that the "penny wise and pound foolish" illustration should be expanded to include the fact that bonded men are required to watch the pennies, while, more often than not, no one is even assigned the job of making a report on what happens to the pounds of coal.

So far no one has mentioned the fact that high-grade operators can obtain better results than a larger crew of poorly trained men.

This has been proved many times and is so true that it can be stated as a fundamental law as far as it concerns supervisors and foremen. It does not mean that each class of work does not have a practical limit, but in each class of work the better man at the higher rate will usually prove the more economical.

Most industrial power-plants of to-day are operated in about the same fashion that central stations were operated twenty years ago, when the chief carried most of the records in his vest pocket and tried personally to direct every detail of the work. He certainly got a good close-up view of many details, but never saw the work as a whole. To-day a good organization is systematized so that the cost books are used as compasses to guide the policies in the most economical direction.

I should like to cite definite illustrations in which vast sums of money have been saved by the change in policy, but, because most of the characters are still engaged in earning a livelihood, it would appear uncharitable to record the productions which could well have been staged under the title of "warring on wastes."

Mr. Lawrence has cited the case where the policy of employing a poor engineer resulted in a great loss. None of the gentlemen who discussed the paper has called attention to the fact that the use of good operators often results in a decrease in the number of operators required, and always decreases the cost of labor and material for maintenance.

Experience in the rehabilitation of many large and small power stations has proved the great value of education in that class of work. A doctor's degree may not be necessary, but there are problems and rewards which challenge and justify the most learned. As stated earlier in the paper, each class of work has a practical limit, but in each class the better man at the higher rate will usually prove the more economical.

The first subject this morning was of especial interest to me, but I did not want to take your time because I thought you would hear too much of me to-day. However, I can not keep from talking about the relation between "percentage of rating" and boiler-operating conditions.

To-day, we are expressing ratings in terms of very large figures, but with the addition of economizers and air heaters and the reduction

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in boiler surface with respect to furnace capacity, "percentage of rating" has lost its exact significance and means nothing. I have been hoping that someone would suggest a better basis of comparing boiler operation.

In the past, boiler rating has been used as a basis for comparison of investments, economy, and maintenance resulting from excess temperature and heat-transfer conditions. Obviously, changing the classification of heating surface from boiler to economizer or air heater has affected the percentage of boiler rating without changing the actual conditions. It would seem that there is a need for some new basis which will give a definite index.

Investment, operating economy (including power required for induced draft), and maintenance represent a three-phase figure, the elements of which are related among themselves and have a relation to the pounds of steam being produced per hour.

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SOME ECONOMIC FALLACIES IN ISOLATED POWER-PLANT COST ANALYSES*

By F. M. Van Deventer†

It may seem to be a waste of effort to discuss here the important part which "fixed charges" play in the true cost of any plant operation. Engineers should be thoroughly conversant with this situation. However, a perusal of the many articles on industrial power-plants in our leading power journals indicates that many engineers either are blind to the real facts; or, ostrich fashion, they ignore the facts in order to prove a specific result. Furthermore, the proceedings of this session will no doubt be used by non-technical executives at large, as well as by engineers, as a guiding text in studying their power-cost problems. It therefore seems appropriate to illustrate by specific example some common fallacies in cost analysis, and to outline a more accurate method of procedure.

Unfortunately, the arguments presented herein are, in general, more favorable to one side of the problem of purchased power. The object of this paper, however, is not to prove that one or the other case is the rule. The author admits that each has a logical existence; but, in order to make a correct decision, each case must be carefully analyzed according to the local conditions imposed, and all tangible items should be given proper consideration. The real object of this paper, then, is to point out how the consideration of fixed charges may be the crucial point in making a correct decision.

With this purpose in view, reference is made to Table I, which is an extract from a recent issue of a prominent power magazine, and which appeared under the title "New . . . Power Plant to Repay Cost in Five Years."

Previous to 1929 the plant purchased electric energy for power and produced process steam in a battery of obsolete Scotch marine boilers. On the strength of the published comparison, the plant was rehabilitated by the installation of a modern boiler plant, a condensing turbo-generator arranged for the extraction of process steam, and the substitution of alternating-current for direct-current motors.

*Presented October 1, 1929. Received for publication January 17, 1930.
†Mechanical Engineer, Henry L. Doherty & Co., New York.

TABLE I. CAPITAL EXPENDITURE REQUIRED

	Column 1 Published cost of boilers, generator, etc.	Column 2 Author's suggestion Boilers only rehabilitated
Boiler settings and ash pockets	$ 13,100	$ 13,100
Two boilers and superheaters	43,330	43,330
Pumps	5,657	....
Piping new boilers	43,671	43,671
Stokers	21,015	21,015
Turbine and switchboards	49,130	....
Condenser	4,006	....
Ash-handling equipment	12,713	12,713
Coal-handling equipment	4,006	4,006
Extending chimney	2,890	2,890
Changing motors from direct to alternating current	7,677	7,677
Changes in building	40,108	20,108
Electrical work in power-house	6,674	6,674
Removal of old switchboard	825	825
Pipe covering	1,618	1,618
Revamp boiler feed treatment	1,953	1,953
Furnishings	340	100
Total capital investment	$258,713	$179,680

Column 1 of Table I shows the itemized cost of the required changes in connection with the rehabilitation of the plant. It should be noted that the total capital expenditure required is $258,713.

Columns 1 and 2 of Table II are also taken from the published article, and show the comparative annual operating costs before and after the rehabilitation. It should be noted from Item 6 that these costs are respectively $97,913 and $46,524. Item 8, the difference between the foregoing figures is $51,389, which properly represents the annual saving in operating expense. It is noted that this saving is just one-fifth of the capital expenditure required. With this fact in mind, the authors conclude the article by stating, "Thus it appears that the saving in operating costs will pay for the new plant in about five years."

The foregoing analysis is typical (unfortunately) of hundreds that have been made, and many of them published as examples of good operating finance, and the conclusion seems logical if one is will-

TABLE II. YEARLY OPERATING COSTS

Table as published

	Column 1 Purchased power 1927 (actual)	Column 2 Isolated plant 1929 (estimate)	Author's suggestion Column 3 Boilers only rehabilitated
1. Labor	$18,924	$ 9,636	$ 6,000
2. Repairs	8,200	2,000	1,000
3. Coal	50,939	33,310	30,000
4. Supervision	1,578	1,578	1,578
5. Purchased power	18,272	....	18,272
6. Total operating cost	$97,913	$46,524	$56,850
7. Less estimated cost	46,524		
8. Saving in operating expenses	$51,389		
Author's complete cost analysis			
6. Total operating cost	$97,913	$46,524	$56,850
9. Fixed charges on capital investment	....	38,806	26,952
10. Corrected comparative production cost	$97,913	$85,330	$83,802

ing to ignore the inevitable laws of economics and finance. While the method is erroneous, or at least incomplete, the conclusion may or may not be erroneous. If it is not, it is in spite of and not because of, the judgment of the analyst. If the conclusion is erroneous, the actual cost of providing the service will be excessive, and the net profits of operating the business somewhat decreased over a period of years; but in this case the analyst would be unaware, because his erroneous method of observation would still indicate a saving.

Of course it is obvious to you that the fallacy of the foregoing example is that the saving in operating expense is not a true or net saving. A fitting slogan would be: "Ask the man who pays the bills; he knows."

The little matter of $258,713 must be procured from somewhere. If it is borrowed, the exchequer will receive the equivalent of an annual statement for about $18,000 for interest. If the principal sum be diverted from a capital surplus account, the possibility of using this amount for dividend-paying investments is precluded, and the six or

seven per cent. return sacrificed. By expending the sum for expansion of the business, it might return 20 per cent. annually, or even 100 per cent. or more. At any rate, the rental value or interest charge on the capital amount exists and must be considered as an item of production cost.

Then the tax assessor strikes his blow. It might be assumed that previous assessed valuations will be continued and not increased by the rehabilitation of power equipment which might escape the notice of the assessor. On the other hand, a dingy and unkempt factory might well be betrayed by a shiny new engine, to the extent that the assessor, dazzled by the nickel-plated mountings, would raise the assessed valuation on the whole factory, on the assumption that the property has been modernized and the value greatly enhanced. At any rate, installed power-producing equipment should be debited with its share of the taxes.

The equipment must be insured. Fly-wheel insurance, boiler insurance, liability and compensation insurance are required to protect the owners. Certainly the cost of these, even though they may constitute a small amount, is a legitimate charge.

The aggregate amount of interest, taxes, and insurance will vary for specific cases according to conditions, but for illustrative purposes will be assumed to constitute an annual cost of 10 per cent. of the capital investment. Referred to the example under discussion this would amount to $25,871. Thus, when all items except depreciation or obsolescence have been accounted for, the net annual saving would be not $51,389 as indicated in Table II, but $25,518. Since this is roughly 10 per cent. of the capital investment, it may truthfully be said that the isolated plant will pay for itself in about ten years; this, of course, is still an attractive proposition, if the present owners expect to operate the plant for more than that length of time.

To illustrate further a possible condition, assume that the capital investment required were double the actual amount, or $517,426. Then the aggregate of interest, taxes, and insurance would be $51,742 a year. Since this exceeds the saving in operating expense, it is obvious that the isolated plant *never* would pay for itself, and would actually entail a higher production cost than purchased power; but, even in this case, the "ostrich type" of analysis, which ignores all fixed charges, would indicate that the saving would liquidate the first cost in five

years. This example may appear to be a travesty, but actual cases could be cited which fall into this class.

Although the author has carried out the determination of "years required to liquidate first cost" for illustrative purposes, four reasons may be cited for discouraging the use of this datum:

1. The real interpretation of the "paid in 10 years" case is that during the first 10 years all savings after costs have been paid would be used to retire a portion of the principal sum. After complete retirement, only taxes and insurance need be deducted from operating savings to determine net annual savings; but this type of analysis is not desired by the executive, who prefers all costs either on an annual basis, or per unit of factory product.

2. The author has shown in another paper* that for some types of equipment the use of "years required to liquidate first cost" or "per cent. return on investment" as criteria of value, may result in the adoption of the *worst* instead of the *best* proposition.

3. It is the practice in most large enterprises to combine cost of plant improvements in a composite fund. The money is obtained by floating a bond issue and amortized by a sinking-fund. Thus, the principal is not paid off piecemeal once a year, but retired completely from the sinking-fund at a specified time.

4. There is a mathematical inaccuracy in nearly all "years to pay" considerations by virtue of the fact that the interest charges theoretically should be reduced as the principal sum is retired. A true solution is somewhat laborious and wholly unjustified.

As a recommendation, the simplest method of analysis which properly accounts for fixed charges may be outlined as follows:

1. Establish a logical assumption for the economic life of the equipment.

2. Charge simple interest on the principal for the entire economic life.

3. Provide for the retirement of the principal by a sinking-fund at the termination of the economic life. Thus, 3.36 per cent. set aside

Trans. A.S.M.E., 1928, v. 50, FSP-50-63, p. 107-114.

annually and compounded annually at four per cent. will amortize the principal in 20 years. (In this manner interest is accumulated on the sinking-fund instead of being saved by the partial retirement of principal. This explains the reason for item 2.)

4. Establish an annual fixed charge by combining the amortization of the sinking-fund with interest, taxes, insurance, etc.

5. The sum of the annual operating cost and the annual fixed charge results in a truly comparative annual production cost.

In Table II the author has appended items 9 and 10. For illustrative purposes it is assumed that the total fixed charges, including amortization, aggregate 15 per cent. Item 9 shows that charge against the investment for plant rehabilitation in column 2. Then item 10 shows the comparative production cost. It should be noted that the comparative production cost for the isolated plant is $85,330 a year, which is $12,583 less than the set-up for purchased power. Thus, on the basis of these two set-ups only, the complete analysis confirms the original conclusion that the production cost with the isolated plant would be more favorable than the former method of using purchased power, but the real saving is only $12,583 a month instead of $51,389 as reported.

Another fallacy, or rather shortcoming, of many analyses is the failure to consider all the possibilities of rehabilitating an isolated power system. A complete study may involve the comparison of a half dozen or more possible ways of providing the necessary power and steam. One of these will attain the objective at a cost lower than with any of the others. If this best method is overlooked, an inferior method may be adopted, with a consequent burden of excessive production cost.

For instance, in the previous example the boiler plant could be rehabilitated so as to reduce the cost of steam production and power purchased. At the outset this might seem to be a superfluous consideration, particularly in view of the one-time slogan: "If process steam and power are both required, use the same steam twice and get the power for nothing." Experience has shown that this is an unsafe rule to follow, and the present case proves the point.

Referring to Table I the author has appended column 2, which includes only the items necessary for the rehabilitation of the boiler

plant. The capital investment in this case is $179,680 instead of $258,713 as required for the self-contained plant.

Table II has been extended by adding column 3, which shows the comparative operating cost with purchased power and a new boiler plant. The total operating cost, including purchased power, is shown by item 6 to be $56,850 a year, or $10,326 more than the operating cost with the isolated plant. An "ostrich-eyed" analyst would immediately abandon the last scheme because of excessive operating cost; but in the complete analysis, as represented by items 9 and 10, it is seen that the saving in fixed charges more than counterbalances the additional operating expense, and the latter scheme actually provides steam and power at a saving of $1528 a year as compared with the self-contained plant, and $14,111 as compared with the original steam plant and purchased power. Thus, even though the author's complete analysis confirmed the published conclusion so far as the two original alternatives were concerned, it is now observed that it would be still better to continue to purchase energy and rehabilitate the steam plant only. There may be still other possibilities which would result in still lower production costs, but that is a problem for the engineer who has complete information on the situation, and who is paid for the work.

The foregoing example was not used with any malice aforethought so far as the particular plant is concerned, but only because it has served so admirably to illustrate two very common fallacies.

In conclusion, the author wishes only to emphasize the importance of fixed charges as constituting a large portion of production expense, and to point out that a complete consideration may involve the comparison of many possible set-ups instead of only two alternatives.

While a problem of "purchased power versus isolated plant" was used for illustrative purposes, the same factors are of equal importance in selecting the type of equipment to be used within a specific plant, or in any similar problem of design.

Inasmuch as the techincal press is represented at this meeting, I shall take the liberty of speaking somewhat more critically than might be considered proper if there were not some one here to represent the publishers.

Of course, it is an important function of power-plant journals to publish data on plant improvements as examples of the benefits to

be derived therefrom. Moreover, it is not to be expected that 100 per cent. accuracy ever will be attained in the analysis of all rehabilitation problems, nor does the fact that some published analyses are subjected to criticism limit the credit which is due to the authors and publishers for their conscientious effort to serve the profession; but the important point, as I view it, is that the principal value of such articles lies in the fact that they serve as valuable guides to others, not in the adaptation of the conclusions per se, but in the presentation of the information and the *method* of analysis which warranted the conclusions. It thus becomes the duty of an author to submit a true and complete set of facts in justification of the conclusions he presents; and it is equally incumbent upon the publisher to present the information in such a manner as to preclude the possibility of misinterpretation by the casual reader. It therefore seems appropriate to urge technical editors to scrutinize carefully all such articles and to point out limitations of the facts and conclusions; and, above all, to select titles with accuracy of interpretation rather than spectacular display as the major purpose.

Referring to the specific example which I used, a manager of a similar industrial plant, in glancing through the pages of the publication referred to, would be attracted by the headlines. He would be interested in knowing whether a similar rehabilitation of his plant would also pay for itself in five years. Following the line of least resistance, he would use the method of analysis as published, altering such figures as might be required to make the set-up represent his conditions. But, since fixed charges did not appear in the article, and since publication implies, to a certain extent, concurrence on the part of the technical editor, he would in all probability ignore that item of cost. The factors governing his case might be such as to result in higher total costs after rehabilitation and abandonment of purchased power than under existing conditions, but the incomplete analysis would undoubtedly indicate "that the investment would be saved in a few years."

My earnest recommendation is that operators present complete production costs including fixed charges, and, in cases where these are not available, an editorial note be appended to point out the limitations of the data.

DISCUSSION

W. N. Flanagan, *Chairman:** This paper has not only been interesting, but it has been presented in a manner tending to call out discussion. I will call on Mr. Blake to open the discussion.

A. D. Blake:† Very often certain factors which govern the decision are not indicated by the actual calculations. Sometimes those factors are business reasons, and I know a number of cases where these governed the decision to purchase current, although the calculations showed the generating plant to be the more economical.

Referring to the article which has been questioned by Mr. Van Deventer, I took up this point with the man who wrote the article. He told me he had discussed it with the vice-president of the company owning the plant as to why these comparisons with purchased power had not been included. He said there were other reasons that prompted them to leave the comparisons out of the paper. The article was, therefore, built, not around purchased versus generated power, but around the modernization idea, considering savings against the old plant. I think you will find that as the theme of the article. The other question was not introduced.

Furthermore, the power-plant has steam capacity to take care of considerable extension of the manufacturing plant. That may account for the relatively high investment costs. I agree with Mr. Van Deventer that the fixed charges should have been included. As to whether obsolescence and depreciation should be included, that is a question that is debatable when you are considering it on the basis of investment return. Taxes and interest, by all means, should have been included, if you are looking at it from the standpoint of the plant paying for itself in five or ten years. Some will insist that you should include amortization and depreciation; others will argue that you should not.

F. M. Van Deventer: The author well understands the difficulty in obtaining figures concerning fixed charges, and sympathizes with the publishers in their efforts to obtain such information.

The article under discussion is of interest and value within the scope which Mr. Blake says was intended—to describe the modern-

*Special Engineer, Carnegie Steel Co., Pittsburgh.
†Managing Editor, *Power*, New York.

ization of the power equipment; but the headlines and conclusions featured the economics of the situation, and the conclusions as stated are not justified by the data submitted.

So far as my reference to the publishers is concerned, I did not have in mind one particular article so much as a rather general practice of featuring modernization programs, so often presented on the basis of unsound economics. For example, a single recent issue of a popular journal carried three such articles, two of which implied that the isolated generating equipment was justified by the joint use of steam for process and power, while the third indicated that the saving in operating cost would pay for the investment in a few years. These opinions, of course, are factors in favor of isolated generating equipment, but they are not prima facie evidence that the expenditure was justified, though the reader would quite naturally draw that conclusion. That is the crux of my criticism.

I thoroughly agree with Mr. Blake that in determining "years to repay cost," amortization should not be included as an item of cost, though taxes, insurance, and interest on investment during the time of paying off should be. But, as I have already indicated (with reasons given in this paper), I disfavor the use of "years to pay," because that datum is too often misused. If properly applied, it will indicate whether a certain investment is an attractive one, but it can not be used for the relative evaluation of alternatives. It is, therefore, better to use a method which does not have these objections. The method which I favor was presented before the American Society of Mechanical Engineers in the paper already referred to, and it has stood the gaff of critical examination by engineers who are proficient in this field of endeavor.

W. B. Skinkle:* Unfortunately I was called out while the paper was being read but I looked it over a little before coming to this meeting. Mr. Van Deventer calls attention to the fact that local conditions very frequently control what is done. I think local conditions surrounding each development probably control the most important factors entering into the problem. I do not think there is any subject which is more thoroughly misunderstood than the subject of costs, fixed charges, and credits as between the products of the same

*Engineer, Pittsburgh District Power Committee, Subsidiary Companies of U. S. Steel Corporation, Pittsburgh.

company; and the difference between actual money and "book values" placed on by-products which are incidental to the manufacturing process. The whole thing often sums up into a very confused mass of material. Mr. Van Deventer has treated a very important subject in a very enlightening and intelligent way and I hope more papers along the same lines will be presented in the future.

L. J. Lamberger:* I have nothing to add except that in analyzing power costs for industrial concerns we have difficulty in getting all items of expense included, particularly space values and fixed charges.

I am glad that the matter of articles appearing in technical journals has been brought up because, on the subject of power costs, we read quite a number of articles that are misleading. I heartily agree with Mr. Van Deventer's recommendation that the publisher go over these articles more carefully to make certain that the article does not give an incorrect impression. I should think that publishers would be very careful about this, as a poor or incomplete article would only be a reflection on the quality and value of the journal. We must bear in mind that hundreds of business men and students in our technical schools, who have perhaps not had enough techincal experience to form an opinion of their own, read these articles and are apt to be misled if the article is not complete and does not give a true picture.

W. N. Flanagan, *Chairman:* I think the point Mr. Van Deventer raised is well taken. On the other hand, I have noticed that many of the journals, when somebody disagrees and writes a letter to them, will publish the letter and give it prominence. Oftentimes the letter does correct previous mistakes and very often arouses a lot of interesting discussion. Most of the modern publications are very free to publish criticisms of their articles if the criticisms are properly presented. Such criticisms, if followed up, lead either to a correction or a justification of the original article.

There is going to be room for considerable argument on the amortization of some of the isolated plants, judging from trade publication advertisements of machinery finance companies financing new installations in power-houses and other industrial enterprises. If

*Director of Power and Sales, Duquesne Light Co., Pittsburgh.

some of these finance companies charge the same rate of interest that is collected in automobile financing it will take a considerable saving to justify the installation. Has Mr. Van Deventer ever analyzed any of these financing charges?

F. M. Van Deventer: I have not had an opportunity to study a representative contract of the type used by the machinery financing companies, but I have analyzed the building and loan plan. The two are based upon the same general principles. In the building and loan plan a uniform monthly instalment is paid. Out of this instalment, interest is charged on the unpaid balance during the preceding month and the remainder is applied on the principal. In this way the debt will be paid in about twelve years. If interest is charged at six per cent., the total amount of interest will be about 40 per cent. of the principal. For example, if $10,000 is borrowed, the borrower will pay 140 monthly instalments of $100 each—a total of $14,000, of which $10,000 is the principal sum and $4000 is interest during the period of paying off. Such a transaction is entirely legitimate, and equally so is an arrangement whereby an equipment manufacturer agrees to accept payment in terms of a monthly instalment equal to the amount formerly paid to a utility company for purchased power.

In the latter case, however, the purchase price is usually (and properly) adjusted so that the financing company will receive proper interest on the deferred payments. The total cost is thus substantially the same whether the financing is done through a financing company or through the use of existing funds, or otherwise.

The unfortunate phase of both of these propositions is that they are often misunderstood, partly because of misrepresentation on the part of the promoter. For example, a favorite argument of realtors is represented by the following:

"Mr. Jones is paying $100 a month rent for an apartment or house. This may serve him well as a home in which to live, but the money paid for rent is 'water over the dam,' and even after a period of years there is no value to show for the expenditure; whereas, if Mr. Jones will liquidate some securities which he owns so as to make a first payment of $5000 on a nice new home in Sunset Hills, and then apply to a building and loan plan the $100 a month formerly paid for rent, he will then be his own landlord, and will own his home outright in 12 years, having paid for it with the rent money."

The realtor fails to point out that in addition to the $100 a month to the building and loan, Mr. Jones as his own landlord, must take care of his own taxes, insurance, and maintenance, and that he will sacrifice the dividends formerly received on the securities. An evaluation of these items on the basis of an actual case shows that during the 12 years Mr. Jones would pay the building and loan company $14,000 for principal and interest. He would also pay $8500 for taxes, insurance, and maintenance, and the $5000 worth of securities, if they had not been disturbed, would have been worth $10,000 at the expiration of 12 years, taking credit only for accumulated dividends reinvested annually. Thus the total capital outlay for 144 months would be $32,500 or $226 a month. This might be a considerable burden, especially if Mr. Jones's income was closely budgeted when paying $100 a month for rent. It is true that Mr. Jones now owns his own home; but, if it be valued at the original cost of $15,000, the net cost for housing for 144 months would be $17,500, or $122 a month. This figure also represents almost exactly the monthly cost for the items which remain even after completion of the time of paying off. I do not claim that this would not be a desirable thing to do, but the true statement of cost is entirely different from that described by the real-estate agent.

I have been confronted with several parallel cases in the power equipment business wherein an agent proposes that the customer pay for the equipment by turning over to the financing company only the amount formerly paid for utility power, so that ostensibly he will eventually own the equipment with no more financial burden than when purchasing power. But the contract cost of a machine is a small part of the installed cost including real estate, buildings, piping, auxiliary apparatus, etc. When these and the increased cost of isolated-plant operation are evaluated, it is sometimes found financially desirable to install the equipment and sometimes not. Other factors to be considered are reliability, the flexibility of expansion, the possibility of liquidation upon sale of the factory, the trend of wholesale electric rates, and the effect of dull business periods upon costs. The cost statement thus represented is quite different from that presented by the equipment salesman, and the important fact is that, regardless of the method of financing adopted, the cost is truly determined by the method outlined in the paper, giving additional consideration to the factors enumerated in the foregoing paragraph.

W. N. Flanagan, *Chairman:* Undoubtedly there are on the road 100,000 automobiles that would not be there if it were not for the financing companies. When you come to figure interest, however, you are rather shocked. What I had in mind about machinery financing was whether it has been developed so that a lower rate of interest would carry the business.

A. D. Blake: The answer to the automobile question is that there are a lot of automobiles on the streets to-day that would never have been bought if it had not been for these financing companies, and the owners had been compelled to go to the bank to borrow the money.

The idea, applied to plant financing, I imagine, is more costly than borrowing from the bank, but it will result in more plants being modernized; for, where the owners have to borrow the money from banks, the loans sometimes carry strings such as bank representation on the board of directors and things of that sort.

H. P. Smith:* I am sure that many of us have had experience with fallacies of cost analyses and consequently Mr. Van Deventer's paper has been of great interest to us. In all probability certain isolated plants are still operated in this territory because reports justifying their continued operation contain fallacies.

There are other factors which affect the decision as to the abandonment of isolated plants but which can not be classed as fallacies, even though they may cause a plant to be retained. One instance that I have in mind is a gas-engine plant which is still in operation after other power-plants of the same corporation have been abandoned. This situation was puzzling for a time until it was learned that the head of the organization had himself laid out the plant and took such pride in the installation that he did not care to see it replaced by purchased power.

An example of a fallacy of cost analysis may be had where the monthly costs of several plants belonging to the same organization are closely compared. A factory generating its own power has an unfair advantage over one purchasing its power, if the fixed charges of the isolated plant are not considered as part of the cost of the power generated. This sort of fallacy may cause the individual re-

*Director of Rates, Duquesne Light Co., Pittsburgh.

sponsible for low monthly unit-cost figures to hold to the isolated plant even though the total cost of power is greater than the cost of purchased power.

F. M. VAN DEVENTER: Was the gas-engine plant you referred to retired about the year 1923?

H. P. SMITH: No, the plant is still operating.

F. M. VAN DEVENTER: It is a peculiar coincidence that the conditions you describe are identical with those in a gas-engine plant in this district, which I analyzed for the owners in 1923 as a disinterested consultant. This plant also was designed by the president of the company and was one of his hobbies. It was 20 years old, and the owner steadfastly refused to give any consideration to fixed charges "because the plant had paid for itself." Therefore, though such a consideration was and is contrary to my judgment, operating costs only were compared with purchased power.

Purchased power was recommended on the basis that the cost would approximately equal the operating cost of the isolated plant under existing conditions, but that substantial savings could be made through a reduction of the demand charge by making certain changes in the electrical hook-up and installing step control on compressors and hydraulic pumps, these entailing no capital outlay.

During the first six months on purchased power, the cost per kilowatt-hour was more than one per cent. lower than the operating cost with the gas-engines. Then the recommended operating changes were made and during the next six months there was a reduction of 30 per cent. in cost per kilowatt-hour. This saving could not have been made with the existing isolated plant, even by altering the mode of operation.

This is mentioned not to prove that all gas-engine plants should be abandoned, but to show that a true determination of the cost of purchased power involves more than the application of published rates to existing load characteristics.

J. H. LAWRENCE:* I was very much interested in reading Mr. Van Deventer's paper because it seems to me it is a severe indictment of the engineering profession, and I think we deserve it because there is no subject on which engineers are more ignorant than on the matter

*President, Thomas E. Murray, Inc., New York.

of financing. I do not think we should criticize the magazine in question too severely, because the editors print what is common language among industrial executives and engineers.

If you will go to almost any industrial manager and ask him what return he expects on an investment, he will say that he expects, say 33 1/3 per cent., or his money back in three years; or 25 per cent., with all his money coming back in four years. We have heard this very statement many times, even in recent years and from executives of some of the largest corporations in the country. As a matter of fact, they do not get their money back in three or four years, whichever may be the case, as interest, insurance, and taxes must be deducted from the gross savings.

As Mr. Van Deventer points out, we should at least endeavor to have engineers present the facts, and not publish figures which are misleading.

It appears to me that the plant under discussion never should have been built if the estimated savings were only $50,000 a year on an investment of $250,000. This shows only 20 per cent. return on the money, which in an average industrial plant is not sufficient return on an investment. There are some industrial concerns which will figure a lower return as being profitable, but, ordinarily, 20 per cent. is the minimum.

I think this organization could accomplish a lot by calling attention to the very important subject of fixed charges. We figure efficiency and savings to the last degree, and then when we get to the item of fixed charges, we use a factor which may vary from 10 to 20 per cent. There seems to be very little knowledge among executives and engineers as to the basis of this item of fixed charges, and generally a percentage figure is used because it has been used by some one else, who was probably also ignorant of the make-up of this item.

I have discussed this matter with auditors of large utility companies and could obtain very little information from them as to the value of the component parts of fixed charges.

A. Helkman:* If you could amortize a plant by including in the fixed charges during the life of the plant a sinking charge, would you want to accumulate a fund during the economic life of the plant?

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J. H. Lawrence: It all depends on how long you want to take to pay it off. Most industrial concerns do not want to take many years to pay off the cost of the plant. It may be that in 10 years the plant will be out of use. There is a limit to the life that you can expect of an industrial plant. Consider the New England textile plants at the present time. Most of them are shut down.

We can not expect plants to continue in business forever. Due to change in models or changes in styles, a plant will sooner or later be abandoned unless it is turned over to some other use.

Before you start, you must estimate on a certain life of the business, or your calculations do not mean anything. The plant and equipment may still be in good condition at the end of the expected period, but if they can not turn out salable products, what good is the investment?

At the end of the period you have your money back, but what have you of value in your plant? The plant may be in 100 per cent. condition at the end of 10 years, or it may not be good for anything. If it is in good condition, is it of any value if you have no market for the product? You should figure a definite length of time during which your investment is gradually being used up, and assume that at the end of that time it will not be of any value to your company. You have to make some such assumption in order to figure out your expected costs.

W. B. Skinkle: Mr. Lawrence made the statement that it would be an excellent idea for the engineers to begin to educate their clients in financing. Judging from some of the reports that have come to my notice from time to time I think that it would be a good idea for the engineers to start a vigorous campaign to educate themselves in finance.

F. M. Van Deventer: In closing this paper I would like to emphasize the relative importance of one of the component items of fixed charges; namely, taxes. A recent survey has shown that the average utility company serving large metropolitan centers pays more money annually for taxes alone than for fuel. Since we devote so much time to the consideration of the things which affect the cost of fuel, certainly we are justified in stressing the importance of fixed charges as an item of the cost of power. Of course, an industrial plant does not

spend as much for taxes on its power equipment as for fuel. A large part of the investment in a utility system is in the distribution equipment. For example, a high-tension line about twenty miles long serving the metropolitan district of New Jersey passes within a few miles of my home. The average cost of the right of way, exclusive of towers and line material, was $110,000 a mile, and one single mile cost $1,000,000.

If this discussion does no more than set aright a single industrial-plant owner who might otherwise have reached an erroneous conclusion concerning his power equipment, I believe our efforts will have been well spent.

STEEL-PLANT COSTS FROM THE STANDPOINT OF THE AUDITOR*

By W. H. Dupka†

There are a number of reasons why the viewpoint of the auditor with respect to steel-plant costs must of necessity be different from that of the engineer. There should not be any serious difference of opinion as to the mechanics of cost finding, though there may be in the manner of exhibit or display; but, when there is a thorough understanding of the many purposes for which costs are made, it will be readily seen why all of the views of the engineering profession can not be fully met in the compilation and presentation of steel-plant costs.

At this point it might be appropriate to give a brief description of the cost report of a steel plant. Such a cost report is usually divided into two sections—a general sheet and a detailed exhibit. The general sheet indicates the materials used (shown in detail), the credit for the scrap produced, the total operating labor, total of repair labor and repair materials, and then the so-called running expenses such as tools, lubricants and supplies, refractories, water, steam, electric power, shop expense, proportion of general works expense, etc. To the total of all of the above is sometimes added local taxes and insurance, the final result representing the grand total production cost of the output of the particular unit. The cost for the month for each of the aforementioned items is shown both in total amount and in cost per unit, the cost per unit also being given for each item for the year to the first of the current month and for the preceding year. The general cost-sheet would also show the units produced for the current month, for the current year to the end of the preceding month, and for the previous year. It would also show percentage of yield of finished material, scrap and loss for the same period, the number of turns worked, the percentage of output to capacity, the previous records, both as to cost and production and any other pertinent operating data.

The detailed exhibit would break down into greater detail the items of productive labor, labor for repairs, and items for material and running expense, the extent depending upon the particular unit involved and the desire of the mill management.

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One of the most important functions of steel-plant costs (or for that matter of the costs of any industry) is the valuation of inventories of products and other assets for the determination of balance-sheet position. Values for this purpose must be stated conservatively and must not include profits in any form, such as interest on investment, or other carrying charges. The use of costs for valuation of balance-sheet assets, therefore, precludes the possibility of meeting some of the views of the engineer in the making of steel-plant costs.

Closely correlated with the first function of costs is the second use which we of the accounting profession deem just as important as the first—that of the determination of profit and loss. It is necessary that the progress or trend of a business, with respect to profits or losses, be determined as accurately as possible. Without proper cost information it is possible that incorrect profits may be reported and, as a consequence, dividends may be improperly declared, creditors or stockholders may be wronged, or the business itself wrecked. Furthermore, from the standpoint of federal income tax, it is of course a matter of importance to the business, as well as to the government, that the profits be stated as accurately as possible so that income taxes may be properly assessed thereon.

Another function of costs is their use as a guide in establishing prices by the sales department. A great deal has been said the last few years concerning the sales methods used in the marketing of steel products. It is believed that if all steel company sales departments were adequately equipped with pertinent and accurate cost information, and if they conducted their selling policies on a sound economic basis in accordance therewith, the industry would be able to show a more adequate return on the money invested than it has enjoyed over the past few years.

Still another function of steel-plant costs is their use as a measure of the efficiency of operations. Here, unless the cost-sheet information is properly and intelligently used, is where difficulty will be encountered. For example, merely because the cost-sheet shows that the cost of a particular product for a month is less than in a preceding month, it can not be assumed that a better operation was experienced. The exact contrary may be the case. The data on the cost-sheet may have to be analyzed, we admit, but because that is necessary, it does not follow that the cost-sheet as made up does not serve the other pur-

poses for which it was designed. The foregoing also applies when the cost-sheet information including carrying costs is to be used to determine the advisability of making changes in physical equipment or for the purpose of ascertaining to what extent such change after it has been made has benefited the operations.

Referring to the necessity for detailed analysis when using the monthly cost-sheet data for measuring the efficiency of operations, or the benefits obtained or to be secured from plant improvements, this is necessary not so much because of the way in which the cost-sheet is made, as because of the factors responsible for cost variations, some of which are extremely intangible and difficult to evaluate. The efficiency of labor is one of those factors which, as we all know, has been responsible for wide fluctuations in cost. All we need to do is to compare operating costs during 1917 and 1918 with those of the present; or operating costs immediately preceding and after the installation of a bonus system where it is applicable. Varying production yields substantially affect production costs. Climatic conditions play an important part in steel-plant costs; the effect of summer or winter temperatures and atmospheric conditions influences both output and efficiency. The effect of a drought on the chemical composition of river water results in innumerable difficulties in the operation of power-plant and other steel-plant units. Fluctuating prices of materials, not only of those used in the manufacturing processes, but of supplies and repair parts, influence costs. Changes in wage rates and freight rates, cost of waste disposal, varying rates of operation, all have their effect on costs. Some of these effects can be easily measured; others with extreme difficulty, if at all.

It will thus be seen that monthly cost-sheets can at the best only point out the trend, and for a more intimate view of conditions, a detailed analysis is necessary. This is true with respect to a comparatively simple cost-sheet for a boiler house or electric power-plant, and much more so with respect to that of a highly finished product, such as tin-plate, wire, tubular goods, or cold-finished steels.

For the foregoing reasons the cost-sheet best serves its purpose when it employs figures for a period of more than one month. The average for the period tends to round out the peaks and valleys reflected in the costs of an individual month, and the possibility of reaching erroneous conclusions by cost-sheet comparisons is thereby largely obviated.

A cost-sheet is a historical document, recording faithfully the basic facts that have transpired during the period, and setting forth as correctly as it is possible to determine them, the expenditures incurred in the operation of a particular unit or in the production of a certain lot of material. All of the pertinent information is presented, and the purpose for and manner in which it is used largely determine the value of cost-sheet data to the administrative, financial or mill executive or steel-works engineer.

STEEL-PLANT OPERATING BUDGETS*

By L. C. Edgar†

We, the people of the United States, are, by virtue of our residence in a land of fertile fields and enormous material resources, most fortunate. However, these selfsame fertile fields and enormous material resources are of no avail unless we use them effectively and economically. Our present so-called high standard of living is dependent upon such use, and it is the engineer's responsibility to see that this is achieved, as it is his function to apply physical, chemical, and psychological science and mechanical ingenuity and skill to the furtherance of the effective and economical use of our natural resources.

The productive capacity of a people or nation is, to a large extent, the measure of the extent to which they enjoy the comforts and luxuries of life. The increasing of this productive capacity demands that waste of labor and material be eliminated, for of what use are well-designed plants and ingenious machinery if, through careless management, labor and material be wasted.

We are celebrating the "Golden Jubilee" of the electric light, and since the glow of that first lamp we have absorbed into our national life many things that have increased the comfort and convenience of living, and the luxuries of yesterday are the necessities of to-day. Since that day, fifty years ago, we have the electric light, the telephone, the radio, good roads, and countless other things that make for our pleasure and convenience, but the having of these things places an increasing demand on our productive capacity.

Budgeting is a method of controlling waste of labor and materials so that economy may prevail and our productive capacity be increased.

Budgeting as a principle is as old as man, for the primitive man who laid aside a sack of seed for the next year's planting was budgeting his future requirements.

Our national government must operate on a budget of expenditure, as any other method would result in a chaos of legislation and executive functions.

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†Chief Engineer, Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa.

The well-regulated business of to-day budgets its productive operations on the basis of carefully made sales forecasts.

With this background of successful budgeting, is it not reasonable that uncertain and unreliable standards used for labor and material control in a steel-works should be replaced by a carefully determined and well worked out budget system?

A budget of labor and materials in a steel-works is an allotment of man hours or materials that is considered necessary to carry on the normal functions of the various departments, subdivided in such a way as to focus individual responsibility, and subject to change to meet varying percentages of operation.

There are three main divisions to the work of establishing and operating of a steel-works budget:

1. Determination of proper budget allowances.
2. Operation of budget records.
3. Control of budget.

1. *Determination of Proper Budget Allowances.* As proper budget allowances are absolutely essential to the success of the budget system it is important that this work be handled by capable and intelligent men who have sufficient sympathy and human understanding not to antagonize those with whom they come in contact. The work should preferably be under the supervision of a responsible executive not in an operating capacity, but who has as thorough a knowledge as possible of the plant and its operations.

In my opinion the engineering department is, or ought to be, a satisfactory department for this work, in which case the chief engineer and the general superintendent or general manager should be the only executives authorized to approve or change the budget allotments.

The first step in the setting of a budget is to establish in the minds of the organization a favorable attitude towards the budget method of control. A good way to do this is by departmental meetings, calling together the department superintendent, assistants, foremen, and gang leaders and pointing out to them the advantages of a budget system.

You can not commend to men any artificial plan for making them producers—any scheme for driving them into economy of pro-

duction—you must lead them through self-interest. It is this alone that will keep men keyed up to the full capacity of their productiveness. Emphasis should be laid on the mutual interest of the men and the plant; for example, unless the plant is able to produce satisfactory product at low cost, other plants will get the business, and lack of employment will result. If it be necessary to lay off some men in order that low costs may prevail, it is better thus than that the entire plant be idle and the greater number suffer unemployment.

It should be pointed out to the men that a budget properly set is in the interests of a fair deal to them—that a foremen who is endeavoring and succeeding in making an improvement in his operations has the assurance of a measure of his achievements. Many foremen and superintendents go on year after year with no authentic record of the improvements they have made. The budget provides for this record of achievement.

This method of dealing man to man and the placing of definite responsibilty upon the men will, in the great majority of instances, bring results. The great trouble with industrial relations is that in many cases a vague responsibility for uncertain things is placed upon men to the mutual dissatisfaction of both men and employers. Most men are proud of the work they do, and, if you give them a definite task with a fair index or measure of work done, you will get a favorable reaction. At the plant with which I am connected both the general superintendent and the chief engineer discussed these questions with the men quite frankly and at some length.

The next step in the setting of a budget is the allotment of the proper number of man-hours considered necessary to carry on the normal functions of the departments, subdivided in such a way as to fix on each foreman in the department a definite responsibility for his operation.

A knowledge of past performance is, of course, essential and an investigation is made of the amount of labor used for the various operations as disclosed by past records. With this knowledge at hand, a field investigation of the work is made by the budget men, talking over the work with foremen and superintendents, and a complete verbal or written report of this is submitted to the chief engineer and the general superintendent for their suggestions. In the course of such investigations, many improvements, consolidations of duties,

and economical practices are established. Thoroughness in this work is essential if satisfactory budget settings are to be attained.

When the budget allowances are finally set up, the various foremen are called in and asked to agree to try to meet the budget set or say why they think the allowances can not be met. The budget allowance thus becomes a co-operative proposition, because it is established by counsel and agreement.

At this time, it should be pointed out to the foreman or superintendent that he should do everything possible to equal or better the allotment of hours, and thereby reflect credit on himself and his department. This he may do by more careful supervision, new ways of doing things, changes in equipment to avoid the necessity of undue repair, etc. This has been done by a great many of our foremen and they, one and all, have contributed something to the advantage of the plant and the company, and the aggregate advantage has built up an astounding total of betterment.

2. *Operation of Budget Records.* Having established proper allotments, the second item is to compile and submit the proper records of the operation as shown relative to the budget.

This operation is, of course, a matter for the accountants, and the forms and methods of handling were worked out with them. Our objective was that each day every foreman could be kept informed as to his standing relative to the budget, and that each week a summary of all the plant operations be submitted to the general superintendent for his consideration and for further discussion at weekly meetings of department superintendents.

By utilizing existing time records and dovetailing our budget records into these, we were able to do this with a comparatively small amount of extra clerical help. Each department is thus kept informed of its operating labor as it occurs, and no post-mortems of labor cost are necessary.

3. *Control of Budget.* The control of changes in budget settings remains with the chief engineer and the general superintendent, and a careful investigation is always made before any changes are accepted. The allowances are, of course, varied to meet fluctuations in operation.

This method of labor control can be beneficial only if administered with care and thoroughness. If so administered, it will foster co-operation and counsel and will make each man realize his duty to his employer and himself. It will give him a new sense of fair dealing and will increase his loyalty and stimulate his effort.

In an organization where sympathetic understanding exists between management and men, much can be achieved if proper guides and measures of achievements are provided; but, without such understanding, results from a budget system (or any other results) are difficult, if not impossible, of attainment. The first thing, therefore, is to get close enough to the men to obtain and hold their co-operation and assistance.

A man who is earnestly striving to satisfy his employer will, at once, under a budget system, begin to think of ways and means of equaling or improving the budget set for him or his department. This he can do in several ways. He may plan his work more intelligently, and thereby accomplish more work with the expenditure of the same number of man-hours; or he may be able to suggest or point out some weakness in equipment that can be remedied; or he may make some constructive suggestion as to new and improved machinery or methods to reduce the man-power required.

This plan will promote better conditions throughout the plant because of better discipline and more orderly ways of doing things. It will bring about better maintenance conditions because of better and more intelligent supervision.

In connection with the operation of the budget, emphasis has also been placed on the fact that machinery and equipment must be adequately maintained, and that the plant must at all times be kept in good physical condition.

Our experience has been that the budget has had a tendency towards better conditions of repair and maintenance. This fact is very simply explained, because when foremen and superintendents are operating under a budget system, they must of necessity pay more attention to the jobs at hand in order to meet the budget. Superintendents and foremen must, when operating under a budget system, investigate jobs more thoroughly before doing them, assign the correct number of men to the jobs, and prescribe the way in which the work should be done. Consequently, many jobs that would ordinarily be

left to the judgment of the sub-foremen and gang leaders are, with a budget system, under more competent and careful supervision, with the result that they are done better as well as more cheaply. Furthermore, many improvements are suggested, due to this supervision, that would not be suggested without it.

Another outstanding advantage of the budget system is that it relieves the superintendent of a department of routine duties and permits him to devote more of his time to improving his department. In this age of intense competition in the steel business this is no mean advantage.

A budget system will foster engineering progress because of a better knowledge of conditions by the chief engineer and all other executives of the plant.

The attitude of the chief executive of a plant to the budget, and the degree to which he assumes the responsibility for the preparation and administration, very largely determine the results to be obtained by the use of a budget system.

I feel that such a system of controlling labor and material is based on sound principles of efficient management and, if wisely and conscientiously administered, and worked out to meet the specific requirements, may be of substantial benefit to any plant.

DISCUSSION

B. R. Shover, *Chairman:** Mr. Edgar's suggestions might mean either more or less work for the engineer. The problem is one very largely of psychology, because no matter how well a system of that kind is worked out, if the human element is not given full consideration it is bound to fail. Budgeting is an adjunct to cost accounting, and Mr. Edgar's excellent paper on the subject should bring out a number of ideas at this meeting.

W. A. Drylie:† I happen to be one of the operators who come under the speaker's jurisdiction. He said come in and talk it over. Now that sounds very nice; but it remains with the chief engineer and general superintendent to change the budget. Your whole effort

*Consulting Engineer, Pittsburgh.

†Superintendent Steam Department, Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa.

is to convince them that it requires more labor to carry on your part of the operation. It is really a good thing, because usually you get a number of suggestions from the engineering department that help the operator to do the work in the number of hours allowed. When it started we did not think it possible to meet the budget. The men under me were of the same opinion and asked me to take it up with the chief engineer. We would take it up and in 99 cases out of 100 we would come back with some better method of doing the work and probably in fewer hours than they had allowed in the first place. Mr. Edgar says it requires a lot of work by the head of the department and his assistants. I fully agree with him, but in the end it is a lot easier, because you get the co-operation of the whole engineering department if necessary.

B. R. SHOVER, *Chairman:* In other words, one of the effects of this budget system is better co-operation. Team-work is an essential thing, whether in football, baseball, or steel-plant operation, and if the budget system does not do anything more than to result in better team-work, it has certainly fulfilled one function. Further remarks along this line would be welcome.

G. E. DIGNAN:* Are department productions as well as maintenance handled in the same way?

L. C. EDGAR: As a matter of fact, we do not budget mills in that particular way. In labor in regard to material the labor is usually budgeted on the basis of turns. In other words, it would take a certain number of men to perform a certain function in a mill—a certain number of rollers, a certain number of rail straighteners, and so on for the various operations of the mill.

We will assume that the mill is operating approximately at capacity, at least within the specified limits. When it is operating, it is building up certain requirements for repairs and it has certain requirements for productive labor. The numbers of hours for these particular duties are allowed on the basis of turns. In the blast-furnace it is on the basis of the number of furnaces in operation. In

*Chief Engineer, Davison Coke and Iron Co., Pittsburgh.

cases where you have several furnaces, one of them, by virtue of its arrangement or design, may require more men. Naturally the allotment of men to that furance is different from that with some other furnace; and the allotment of men under a certain product may be greater than with other products from the same mill. We have a mill on sheet bar for a few turns, and it may go over to rolling rails for a turn or two. The allotment of men on sheet bar is very much less than the allotment of men on rails. Under the old system, under many circumstances it was very difficult for us to see to it that when they went from rails to sheet bar for a turn or two they cut the labor off completely. It was always the case that there was a tendency to leave an extra man here and an extra man there and it would build up an accumulation of hours more than was necessary. Under the budgeting system the allotment of hours is cut off when they turn over to sheet bars and the men must be cut off or we will exceed the budget.

The same is true in shops. The tendency is to have shops running and with all the mills going you can cut them to a reasonable volume; but when one mill goes off, the cutting down to the correct proportion is not easy. Under the budget system, when a mill goes down, the number of men on repairs must be reduced.

In the blast-furnaces, labor and materials have been largely set on the basis of turns. There may be some other basis in different mills. In our case we thought turns was the best measure. Turns for different products are different. The gangs differ in number of men, and with various mills on different products the allowance of hours is based on the particular service, and in the case of repairs they follow the same rule. We naturally do not have to maintain men in our shops to repair rail-handling cranes and machinery when we are rolling nothing but sheet bars, and therefore these repair gangs should be cut off. Without the budget, it is rather difficult to determine accurately what men should be laid off, and when.

H. L. PARLETTE:* Does not this laying off of labor at more or less irregular intervals result in a strained condition between the employer and employee? Does not the assignment of a given amount of work to be done in a given period of time cause an attitude of resentment or antagonism on the part of the employee? If such is the case,

*Engineer, West Penn Power Co., Pittsburgh.

what are Mr. Edgar's thoughts on a system of co-operative management?

In speaking of co-operative management I have in mind a plan similiar to that employed by Mr. Mitten in his management of the Philadelphia Rapid Transit Company. Prior to about 1910 or 1912, when Mr. Mitten took over the operation of this company, it was a rather difficult task to find a time when some part of the system was not experiencing labor troubles. Inasmuch as this plan has satisfactorily corrected a very ugly condition in the example just cited, I was curious to know what Mr. Edgar's reaction would be to its application in this instance.

B. R. SHOVER, *Chairman:* Mr. Edgar's plan certainly works for co-operation because it involves practically all of the men interested. Maybe he can tell us whether they have had any trouble on account of resentment on the part of the employees.

L. C. EDGAR: I rather think this is as truly co-operative as we can make it. The bringing in of foremen all down the line (I do not mean superintendents—I mean foremen of gangs) to talk things over with the heads and superintendents and agree upon a definite allotment of hours is genuine co-operation if I know what the word means. Of course I know much might be said to me that could not be said to others in connection with the company, but the general consensus of opinion of our foremen is that they would rather work under a budget than with the old system. They feel that they are getting a fair deal. There has occasionally been dissatisfaction with the allotment, yet patience and discussion and helpfulness will straighten things out, and we have in some cases raised the allotments, though somewhat reluctant to do so except for the possibility of improving the operation.

J. F. BARNES:* I should like to ask whether this budget replaces, and does entirely away with, the older and more common dollars-and-cents system, or whether you maintain the dollars-and-cents budget system in addition for general control of departmental operations.

*Mechanical Engineer, Eljer Co., Ford City, Pa.

L. C. Edgar: We do not allot our labor on the dollars-and-cents basis at all. This is a problem for foremen and gang leaders all the way down the line. It seems to me that foremen of gangs can understand figures a lot better when you talk about hours. Of course we do interpolate the dollars and cents of costs to a certain extent. It is very easy to get costs. We get our costs weekly in some departments. We can forecast our costs in the blast-furnace to a fraction of a cent. We know some months how much our costs have been by interpolating the number of labor hours; and thus money naturally is always available. When you have the record of hours worked, all you have to know is the tonnage, and by checking the budget you know whether or not they are going to make the budget this month.

B. R. Shover, *Chairman:* One advantage of Mr. Edgar's method of budgeting hours is that the records are available for comparison, regardless of rate changes. It ought not to make very much difference whether labor is 40 or 50 cents an hour as far as the number of men required is concerned; but if it is budgeted on the basis of dollars and cents, rate changes will have to be taken into consideration to determine whether the number of men has been decreased or increased.

I should like to ask Mr. Edgar what effect this budget system has on labor turnover. He says that when a mill rolling rails goes on to sheet bars they lay off a number of operators in the mill. They also lay off a number of repair men in the shops because they do not need to tend to the rail-handling equipment. Labor turnover is a very expensive item, and if an arrangement of this kind does not give a man enough employment he is going to seek employment some place else and you have to put a new man on in his place. Have you met with anything of that kind in your experience?

L. C. Edgar: That is a question. Our labor turnover is very much less than it ever was before. My opinion, based on some experience, is that you do not decrease your labor turnover by keeping men on when they are not needed. There is a sound psychological basis for that. Suppose there are two men on a job where one man is needed. They are being kept there because we feel that there ought to be plenty of men around and the operation would suffer if we did

not have enough men around for this or that or the other thing. (It is a good bit of an old-school idea in steel-works management, that the main thing is to have many men around to do what is necessary when things occur that are unusual, such as accidents.) If you lay off one of those fellows and say to the other fellow, we are keeping you on this job because you can do it, he is proud of his work, he has more respect for his job, and he is going to see to it that he holds that job.

It seems to me that this is one of the psychological features of this thing. We can't respect a job that is not a job. We have to have a real job or we do not have any respect for it. Making men feel that they are responsible, and that they are working for themselves, has a tendency to make them feel closer to their jobs. Whether that be true or not, the fact remains that whereas we did have considerable turnover, we no longer have.

W. A. Drylie: The labor turnover has been less since the budget has been installed. Of 150 men employed in the steam department, the labor turnover was about eight men for the year. The men know there are only enough men on duty each shift to carry on the operation and they notify the foreman in advance if they are going to be absent.

RECENT DEVELOPMENTS IN BRIDGE SUPERSTRUCTURES*

By John Lyle Harrington†

Every effect has its cause; so every development in engineering is made to meet a new condition or to cope more satisfactorily with an old one. First the problem, then the solution; first the need, then the means to satisfy it. It is in order, therefore, to look over the conditions and the advances in knowledge which have given rise to the recent developments in bridge design. Probably it is well to define the term "recent." There has been no startling epoch-making discovery, no flash of genius to fix a starting point. The advance has been rather by small increments and easy stages, with but one cause of outstanding importance—the rapid development of the motor vehicle—yet, on the whole, the conditions which govern bridge design to-day differ greatly from those obtaining at the beginning of the century, hence for present purposes we shall consider the changes of the last three decades.

Bridges have been and are required for three kinds of traffic—railway, street railway, and highway—or combinations of these. The standard railway has grown steadily throughout the century; the street railway has waxed and materially waned in importance within a little less than half a century; while the highway motor vehicle, to-day the most important of all, and growing more so, is a thing of a scant quarter of a century. Many times the wise ones have said the railway had reached its maximum development, but, though its mileage now increases slowly, its growth is unabated in size and weight of mechanical units and in economic importance. The electric railway promises to retain a material place in urban transportation, but it is a dying element in long-distance service. The motor-bus and the private motor-car are steadily encroaching upon the passenger traffic of both the older methods of transportation, and at the same time have developed a large traffic that except for them would not exist.

The gage of the standard railway was probably ample for the speeds and weights of train in use when it was adopted, but the pro-

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†Harrington and Cortelyou, Kansas City, Mo.

hibitive cost of making it precludes change to a gage better suited to the present conditions; and the extravagant cost of increasing clearances of tunnels and bridges has restricted growth in height and width of rolling-stock.

Yet, by skilful design, the weight and power of locomotives have been steadily increased. In 1895, Johnson in "Framed Structures"* states that "it is highly probable that the loads now generally assumed will never be materially too small for the actual traffic," and uses Cooper's class "Extra Heavy A," which has 30,000 pounds on an axle; yet to-day 50,000 pounds is considered light, 60,000 pounds is in general use, and 70,000 pounds is not uncommon. This growth in weight has rendered nineteenth century structures obsolete and compelled replacement of most of them.

Highway loadings have increased even more. The weight of the farm wagon, load, and team of the rural districts rarely exceeds three tons in the length of 20 feet; the heavy city truck, load, and team rarely weigh more than five tons; but on both city and country roads to-day loads are limited only by legal restrictions. The 15-ton truck with 12 tons on the rear axle is permitted and provided for almost universally, and a number of states provide for 20-ton trucks with 16 tons on the rear axle. No doubt still heavier loads would be in frequent use but for the legal limits. These loads are more severe on floor systems than any but the heaviest electric cars and, since standard specifications provide for trucks in pairs with heavy uniform loads preceding and following in each traffic lane, to which impact loads are added, highway rather than electric-railway loadings now determine the weight of city structures. The dead loads, too, have been materially increased by the substitution of concrete slab floors supporting paving, for the light, treated or untreated, timber floors of former days.

Density of traffic has enormously increased. Formerly cities had approximately one light, horse-drawn vehicle for each 100 inhabitants, and trucks were restricted to the wholesale and manufacturing districts. The average distance each vehicle traveled did not exceed 10 miles a day. At present the country has more than 26,000,000 motor vehicles, more than one for every five people, and they probably travel an average of fifty miles a day, thus probably increasing the density of traffic one hundred fold. The traffic on the Mississippi

*Theory and Practice of Modern Framed Structures, by J. B. Johnson, C. W. Bryan, and F. E. Turneaure. Ed. 4, 1895, p. 101.

River bridge between Rock Island and Davenport travels in two lanes, but exceeds an average of 20,000 vehicles a day. Trucks constitute about one-eighth of the motor vehicles. They are not confined to limited districts, but compete with railways for long-distance traffic in commodities which take high rates and require costly packing for rail shipment. The buses are taking the coach passengers, even across the continent, and the private car is carrying heavy traffic that formerly used the railways.

The development and use of the motor vehicle created the demand for improved roads and provided the money to build them, for the license tax and the gasoline tax and the bonds issued in anticipation of them have provided nearly all the funds used to build roads. Even the federal aid funds have been largely augmented by the sales taxes on new motor-cars.

The building of roads necessarily involved building bridges, for a highway bridge is but a special means of supporting a pavement. Expediency required that available funds be spent to obtain the largest possible mileage of roads, leaving many of the larger bridges to be provided by public or private security issues and paid for through tolls. The difficulties involved in securing common action on the part of two states or communities caused most of the interstate structures to be left for private capital to build, with notable exceptions at Philadelphia, at Portland, Ore., and between New York and New Jersey.

The greatly increased volume of traffic caused ferries to multiply rapidly, but ferries at best are a makeshift, always involving some loss of time; they are wholly insufficient on holidays and on special occasions, and often out of service for repairs, or because of high water, ice or drift. Bridges have replaced them where public interest was sufficient to provide the funds or where the traffic, present or prospective, encouraged the building of toll-bridges by private capital. To illustrate, between Kansas City and the mouth of the Missouri River, about 400 miles, there were until recently but two highway bridges. Now there are nine. There was no crossing between Selma, Ala., and the sea (150 miles) before the construction of the Mobile Bay bridge. Between St. Louis and the sea there was no highway crossing until comparatively recently when roadways were attached to the Harahan bridge at Memphis; now there are two highway bridges in service and a combined highway and railway bridge under

construction at Vicksburg, Miss. The Ohio River was crossed by one combined bridge between Cincinnati and its mouth. Now it has three highway bridges in that stretch and a score of new ones between Cincinnati and Pittsburgh. More great highway bridges have been built since the automobile became an important element of highway traffic than in all previous time.

Great public enthusiasm for the use of inland waterways developed almost contemporaneously with the motor vehicle, hence the demand for bridges encountered an unprecedented demand for larger clearances for the passage of boats. The development of the vertical lift bridge made greater openings economically practicable and the advance in knowledge of alloys and of heat-treated steels made long spans feasible, while the great development in traffic, and the fact that traffic paid for the structures, warranted the large expenditures involved by larger openings. From ancient times, when water-borne traffic was vastly more important than land traffic, the laws have been most favorable to the interests of navigation; and the engineers of the War Department, who are in authority over navigable waters, have seen to it that bridges have met in full the real and often the fancied interests of navigation in the matter of long spans, both movable and fixed. The vertical clearances have also been increased by reason of the greater ability of the motor vehicle to climb steeper approach grades. The ideal grade for a bridge is just sufficient for drainage, for bridges used by horse-drawn vehicles four or five per cent. has long been considered the maximum grade, while for motor vehicles higher grades are permissible even when they are of great length.

A very few years ago a movable span which provided a little clearance for the largest boat that passed through it met the legal requirement that it be not an unreasonable obstruction to navigation; but, as the water-borne traffic increased in importance, as the use of barges and tows developed and required larger openings and, as improvement in materials and in design of bridges made long spans reasonably economical, greater movable spans were required by the War Department. Years of litigation were necessary to increase the widths of openings on the Chicago River from 140 to 200 feet, measured at right angles to the channel, but to-day an opening of 200 to 250 or even 300 feet is an every-day matter; but, as water traffic grew and competition between terminal facilities became keen, there

developed objections even to large movable spans. Piers and wharves below all bridges gained advantage over those above, real-estate values were affected, and public interest was so aroused that high bridges having spans long enough to clear the whole of the navigable water have become common in busy waterways and in large cities.

To meet the demand for long spans at the lowest practicable cost, alloys and heat-treated steels were developed. Nickel steel was used in the St. Louis Free bridge, the Quebec bridge, the Manhattan bridge, the Detroit-Superior bridge at Cleveland, and similar structures. Then came silicon steel (which is almost as strong as nickel steel and much less expensive), heat-treated eye-bars of still greater strength, and the drawn wire, of yet greater strength, used in suspension bridges.

Esthetics, too, gained in importance and to some extent relieved the engineer of the demand that he design for the lowest possible cost, regardless of appearance. It is but very few years since economy dictated the omission of the modest pylons designed for the ends of the great arch of the Detroit-Superior bridge at Cleveland, and still more recently the modest sum allowed for suitable entrances to the North Hill viaduct of Akron was first reduced by half, then withdrawn entirely, in the interest of economy. The public has been exceedingly critical of spending money to improve the appearance of public bridges, and corporations have as a rule countenanced it not at all. Fortunately, the public mind has been improved and greater consideration is now given to esthetics.

The development of reinforced concrete, which is so well adapted to use in the arch, surely had much to do with the improvement in public taste, for the reinforced concrete arch in general use over gullies and gorges and lesser streams, and occasionally in greater crossings, is in striking contrast to the ugly viaduct and straight-chord truss formerly in use. Sometimes it has caused bitter controversy to secure approval of the higher cost of an esthetic design, but the opposition lessens as public taste is educated to the value of structures of finer appearance, and it is reasonable to hope that in the not very distant future the appearance of a structure may come into importance reasonably in proportion to its utility.

The developments in superstructure design resulting from alteration in governing conditions have been largely those involved in mag-

nitude of loads, of traffic, and of essential dimensions. Substantially every variation in form of truss had been devised and used before the turn of the century and only the Pratt, the Pettit and the Warren remained in general use. A few railways used the multiple-intersection, riveted, Warren truss, because their engineers believed it to be more rigid, better able to carry extra stress and, in particular, less liable to complete collapse if injured by wreck of a train, than the simple, pin-connected structures then in general use.

Two of these views were correct. Movement in the joints, as loads increased, caused uneven wear on pins and eye-bars and so unbalanced the distribution of stress on the bars composing a member that one of a pair often carried all the dead load and materially more than its share of live load. Riveted trusses were free from this defect. Again, in several notable instances riveted trusses survived injuries equal to those that destroyed pin-connected trusses. The three riveted, Pratt-truss spans of the Kansas City Southern bridge over the Kansas River at Kansas City, Mo., were raised and put back in service without repair, after being washed off their piers in the flood of 1903. None of the 18 adjacent pin-connected bridges thrown down at the same time was worth raising.

Engineering opinion moved rapidly toward the use of riveted structures for all but the greater spans, in which live-load stresses were of minor instead of major importance, and in which thickness of metal made uncertain the character of field rivets. Engineers were so dubious regarding the quality of rivets of seven inches grip that those used in the Beaver Falls bridge of the Pennsylvania Railroad and in the Armour-Swift-Burlington bridge at Kansas City, Mo., both built about twenty years ago, were made to fill the hole at the head and were tapered towards the tip, which was cooled before driving, to facilitate upsetting and the better to insure filling the hole. To limit the thickness of metal, gusset-plates of the greatest width rolled were spliced into the main truss members, which had more than 500 square inches cross-section in the Armour-Swift-Burlington bridge. These structures, still among the heaviest of the riveted type, reached and extended the limits of the then current experience in design and in fabrication.

Both the visible distress under load, and extensometer measurements of stress, clearly showed the ill effect of the scant bracing of

earlier railway bridges. The more rigid bracing of recent designs undoubtedly adds materially to the probable life of the structures, yet the older designs can not be considered unscientific. Many a major structure is still carrying modern traffic twice as heavy as that for which it was designed. Low speed substantially minimizes impact stresses, but only counters, floors and a few other weaker elements have been strengthened. The Ohio River bridge at Henderson, Ky., is a fine example of the most effective use of a limited quantity of metal; for its spans, one of which is more than 500 feet long, have pin-connected Warren trusses, hanging floor beams, rod laterals and not a sway brace between portals, yet it continues to carry traffic probably twice as heavy as the loading used in its design. The Wabash Railroad bridges over the Missouri River at St. Charles and over the Mississippi River at Hannibal, Mo., and the Milwaukee bridge over the Missouri at Kansas City, Mo., are other notable examples of old, well designed light structures still in service.

Probably the most pronounced development in form of bridge construction has occurred in the movable bridge field. Until approximately the beginning of the period under consideration the rotating draw span was in substantially universal use, but in narrow city channels it interfered with the use of valuable adjacent wharf property and led to the demand for some form that should be free from this objection. Small retractable draw spans and vertical lift spans had been built in such situations, especially over the canals of New York, but they were crude and ill-favored affairs, of small historic value.

The first bascule and the first vertical lift span of size were built about the same time in Chicago. The cost of the vertical lift was excessive, since the vertical movement required was very great and its machinery was ill suited to the service, for at that time electric equipment was considered too uncertain to be risked; hence both engineering and popular opinion favored the bascule, and its use grew apace. Many engineers developed numerous types, but mechanical excellence led to the wide use of only three—the balanced leaf and counterweight mounted on a simple trunnion, the simple span balanced by a separately mounted counterweight, and the leaf which rolls back on a circular segment. All avoid the use of the draw protection which so obstructs a narrow channel; all move in the plane of

the bridge's center-line, and hence leave adjacent wharves without obstruction; and all cost very much the same. Many other types were tried, but abandoned for these three. The bascule became the fashion, and on that account it was used in many places where it had no advantage over the rotating draw.

As the width of required opening increased, the cost of the bascule mounted rapidly. For the Armour-Swift-Burlington bridge a 428-foot opening was required in a double-track, double-deck structure. The bascule was impossible, hence the writer modified the old idea of the lifting deck to meet the conditions. The mechanical equipment of this lifting deck applied to a proposed double-track railway lift span proved that type to be more economical and mechanically more satisfactory for that situation than the bascule. Further study resulted in the development of the vertical lift span having its operating machinery on the span—a type which is now in very general use.

The vertical lift span is more economical to build than either the bascule or the swing span when the width of opening exceeds the vertical movement required, particularly when foundation conditions are unfavorable—its loads are equally divided between the supporting piers; the towers are light and directly over the piers; the wind loads are low, since the bridge floor is always horizontal; and both counterweights weigh only as much as the lift span. The construction of span and towers is simple, therefore economical to fabricate.

The bascule counterweight must be two to three times as heavy as the leaf it balances, since the counterweight arm must be short; the wind against the floor produces heavy wind loads; the construction is irregular and expensive to fabricate; machinery must be in duplicate and connected by subaqueous cable if two leaves are used; but the type is always advantageous for short spans if great vertical clearance is required.

When the distance from the roadway to the water surface or the use of a subaqueous pit allows the use of a deck structure with the counterweight below the roadway, the bascule always presents the most satisfactory appearance; but, if the counterweight must be placed overhead, there is little to choose between the bascule and the vertical lift span, with its more or less unsightly towers.

In recent times it has been borne in upon engineers that a movable span is a machine which should be designed for hard and unfailing service; not a fixed structure with poorly designed and makeshift mechanical equipment. Unbushed, cast-iron bearings, cast-iron gears with molded teeth, flimsy connections between machinery and structural supports, poor and inadequate brakes, and any kind of a power-plant were once thought good enough for a movable span. Operating troubles were numerous and breakdowns and serious accidents were not infrequent. To-day steel frames and bearings, bronze bushings, forged pinions and cast-steel gears with cut teeth, power as well as hand-operated brakes, duplicate power-plant, magnetic control, and interlocking signals are essential to any first-class structure. In the Duluth bridge—a vertical lift of nearly 400-foot span—a generator with dual power supply charges storage batteries which are connected by duplicate wiring to duplicate motors. A gasoline-engine provides auxiliary means of operating, and two operators are always to be on duty, in order to reduce to the minimum the possibility of failure of the bridge to open. Failure would mean disaster, for boats must come in at full speed and can not stop with safety in time of storm.

Almost without exception, the older fixed structures were made up of simple spans, because the short openings then required made them economical; because their stresses were readily determinate; and last, but not least, because they readily adapted themselves to any movement which might occur in foundations. Piers resting on grillages hazardously placed on top of piles, which were cut off under water and laterally supported by riprap, did not constitute foundations in which great confidence could be placed. Engineers so feared the derangement of stresses resulting from settlement of a pier that continuous spans were inveighed against and avoided, even when the supporting piers rested on rock.

The increases in live loads and in required length of span have added to the economical advantages of the continuous truss; improved methods of calculation have increased the facility and the assurance of accuracy with which stresses may be determined; better methods of construction add to confidence in stability of piers; the cost of erection and the risks involved by high water or running ice are reduced, and the maintenance of navigation is facilitated by the use of the

continuous truss; hence it has been greatly favored in very recent times—in fact, it is becoming so much the fashion that it is now likely to be used where its economy is doubtful. It is not a thing of beauty, yet, with care, its appearance may be made tolerable.

In the Chesapeake & Ohio Railway's Sciotoville bridge over the Ohio River—the first large structure of this type—the continuous truss proved economical because foundation conditions were excellent and two very large openings were required for navigation. This bridge carries heavy railway traffic, and its secondary stresses were of such high importance that they were carefully offset by erecting the truss members in their deflected position. The Mississippi River bridge at Cape Girardeau, Mo., contains two 671-foot spans, the Mississippi River bridge at Chain of Rocks, Mo., just above St. Louis, contains five pairs of continuous truss spans of varying length, and a number of other structures of this type have recently been completed or are under construction.

The merits of the cantilever type of structure have long been understood and appreciated. The Firth of Forth bridge, with its two 1710-foot spans, and still the greatest completed bridge structure, was finished in 1889. The type has been used repeatedly in situations where great length of span was required and where the use of falsework for erection was difficult or impossible. The length of span which makes the cantilever economical in metal varies materially with the loads it is designed to carry, but if the use of falsework for erection is reasonably practicable, the economy of the cantilever is doubtful for spans of less than 700 feet. The economical length of the suspended span also varies with the weight of the structure and the load to be carried, though it may generally be said to be about one-half of the distance between main piers. Objection has been made to the greater deflection of the cantilever than of the simple span, resulting from the concentrated load the suspended span places on the end of a cantilever arm, but this is really a matter of no material importance, and the use of the cantilever is eminently justified for spans of great length, for situations in which falsework is difficult to construct and maintain, and where navigation must not be impeded. It has been used extensively on such busy streams as the Ohio River, and is likely to be used more extensively as the navigation of waterways becomes more dense and less subject to interruption.

Until very recently the cantilever bridge has been our ugliest structure, for economy in fabrication and erection induced straight lines for both the cantilever and anchor arms. The straight top chord, rising from the anchor pier to the main pier, then descending to the suspended span, balanced by a like bottom chord with inverted slopes, certainly did not make for beauty, and the suspended span commonly used, with its straight bottom chord and its upwardly curving top chord, added the last straw in ugliness of line. The so-called K-type of web system, devised for the Quebec bridge, adds, if that is possible, to the ugliness of the structure; but, beginning with the Wabash bridge over the Monongahela River at Pittsburgh, and the Queensboro bridge over the East River, distinct improvement has been made in recent years in the appearance of the cantilever, and in many instances careful consideration of outline has produced distinctive, attractive structures.

It is doubtful whether cantilevers of greater length than those already in existence will be built, for the strength of the metal in the cables of the modern suspension bridge so far exceeds the strength of even the best alloy steels used in built members that the suspension bridge is economically superior to the cantilever for very long spans. In the early investigations of the possibility of bridging the Hudson River at New York, the calculations of Robert Escobar, a very able but little known designer for the Union Bridge Company, demonstrated that a cantilever of 2300 feet clear span, composed of high-carbon steel, was entirely practicable for the train loads of that day, and its then superior rigidity made it preferred to the suspension bridge, but that judgment would probably be reversed to-day.

The failure of the first Quebec bridge has often been attributed to lack of knowledge by bridge engineers of the detailed distribution of stresses in riveted members of the size used, and to lack of experience with so great a span, but the Firth of Forth bridge with spans nearly as great is still satisfactorily performing its office, and the Armour-Swift-Burlington bridge, which was being erected when the Quebec bridge fell, has riveted members quite as large but without the defects which caused failure.

The newer developments in cantilever design are generally confined to details and to appearance, but the form developed for the Allegheny River bridges at Pittsburgh is new and meritorious.

Though it has the form of a suspension span, the absence of horizontal reaction under full load places it among the cantilevers. The rocker shoe of the Beaver Falls bridge insures better distribution of loads on piers; alloy steels extend the economic length of the type; economic limits of length and proportions of suspended span, cantilever, and anchor arms have been determined; and the place of the cantilever in the range of structural types is now well established.

The steel arch has been liberally used where foundation conditions were favorable and attractiveness of appearance was important. It is manifest that economy has also caused it to be used widely in situations where good foundations were available to carry both the vertical and horizontal loads and where a single span was advantageous, such as in the Niagara Gorge, the Deschutes Canyon in Oregon, and in the Fraser River Canyon, for it may readily be anchored temporarily and erected as a cantilever. The arch was distinctly the most satisfactory type of structure for use at Hell Gate and for the crossing the Cuyahoga River in the Detroit-Superior bridge at Cleveland, where long spans were required, navigation could not be obstructed, and conditions were favorable for short spans in the flanking structures. These two great arches which were closed in the same week, the light but long higher arch just below Niagara Falls and the two railway bridges over the Niagara Gorge form notable examples of this type of structure in this country. The great, heavy arch of 1650-foot span, now under construction over Sydney harbor will be the most notable structure of the type, though the lighter 1675-foot span of the Kill von Kull bridge is nearly as important. These structures thoroughly demonstrate the fitness of the type for spans of great length. Because of its attractive appearance the arch merits much wider use than it has been given in situations of lesser importance. Many an ugly trestle, composed of towers or columns and straight, supported spans, might wisely have given place to a succession of steel arches without important loss in economy. The ease with which a straight vertical and horizontal structure may be designed and the eternal pressure upon the engineer to build at the least possible cost have been responsible for many an esthetic crime.

The reinforced concrete arch has become the most favored structure for spans of small and moderate size. A few great structures, such as the Tunkhannock viaduct of the Delaware, Lackawanna &

Western Railroad, the Detroit-Superior bridge at Cleveland and the North Hill viaduct at Akron, Ohio, both over the Cuyahoga River valley, and the Mississippi River bridge at Minneapolis, contain spans of considerable length, but American engineers have never built such long spans as have been constructed in Europe. The excessive cost and the excessive demands upon foundation conditions imposed by concrete make steel the wiser choice for spans of great length.

The idea that concrete structures will never require maintenance has probably been as great a factor as attractiveness of form and appearance in the public esteem of concrete structures; but time is bringing some disillusionment, for discoloration, surface cracking, efflorescence, and streaking from leakage frequently mar the appearance of concrete structures, and defects of construction, which inevitably occur at times, are found to be exceedingly difficult to remedy. If the surface is porous, so that water may enter, deterioration is certain, and is hard to remedy. These facts are becoming manifest to engineer and layman alike, hence the use of concrete is the more definitely being confined to situations where it will prove satisfactory.

The development of the suspension bridge, which has recently come into unusual public favor, was contemporaneous with other types. The first simple span was undoubtedly a log felled across a stream. The first framed structure was undoubtedly a trestle supported on piles or framed bents. Cantilevers of considerable span were built of poles, tied together with ropes, by the Indians of both North and South America; and cables composed of vines, twisted together, long ago were used in foot-bridges built across the streams of India. Coming down to modern times, we find the suspension bridge taking its place in history along with the Fink truss and the Bollman truss. Comparatively early examples were built at Pittsburgh; a very old structure of 500-foot span at Waco, Tex., was long a notable example of the early bridge builder's skill; and there is still in service at Wheeling, W. Va., a comparatively long span which was finished in 1858; but the Brooklyn bridge, which marked a great forward step in the bridge builder's art, paved the way for the great structures over the East River, the Delaware, and the Hudson. Recently the construction of the suspension bridge has become a fashion; partly because of the greater demand for long spans; partly because the graceful curve of the cables, approximating the catenary, appeals

strongly to the newly awakened public demand for esthetic appearance. There has also lurked in the public mind the notion that the suspension bridge is economical as well as beautiful and this has led to its use in many situations where the cantilever, or even the simple span, would prove less expensive.

The determination of the stresses in the stiffening trusses was long a matter of guesswork, and it is still somewhat a matter of debate; for many of the older structures, in which the stiffening trusses would not meet the requirements of present methods of design, have performed their office in a satisfactory manner. The most notable example of this is the most notable structure, the Brooklyn bridge, which has stiffening trusses far less competent than present standards approve.

The Brooklyn bridge with its span of 1595½ feet, completed in 1883, was the most outstanding structure of its time. The lessons learned in its construction were later employed in the building of the Williamsburg bridge and the Manhattan bridge over the East River, and a steady improvement has been made in detail, and the manner and time of construction, in the building of the Delaware River bridge at Philadelphia, the Bear Mountain bridge, and the Ambassador bridge at Detroit. Now comes the Hudson River bridge with more than double the length of the Brooklyn bridge and nearly twice the length of any other, as the most outstanding piece of bridge construction.

The construction of spans of extraordinary length with structural steels of usual grades involves great dead weight and extravagant cost; hence, as demand for long spans grew, the producers of nickel carried out elaborate investigations to determine whether it would produce an alloy of great strength and of reasonable workability at a price which would encourage its use. The alloy proposed after this investigation had such strength that it was believed 30,000 pounds in tension would be a safe working stress, but manufacturers objected to so high an alloy and after much discussion the use of about 3¼ per cent. of nickel was adopted. This produced a steel of 50,000 pounds minimum elastic limit, permitting about 25,000 pounds per square inch as a working tensile stress, but which was yet soft enough to be fabricated without alteration of shop equipment and without excessive cost. Such an alloy was used in the East River

bridges, the Quebec bridge, the Free bridge at St. Louis, the Detroit-Superior arch, and other structures of the time. A little later the experiments conducted by the United States Navy demonstrated that the use of about 0.2 of one per cent. of silicon would produce a steel having an elastic limit of about 45,000 pounds, and safely permitting stresses about 50 per cent. higher than those of carbon steel. The cost in the structure is only about one cent a pound higher than that of carbon steel, hence it has proved economical and has come into considerable use, not only in spans of extraordinary length but in spans down to 400 feet or even less.

Because many metals, each in varying quantity, may be employed, an almost infinite number of alloys is possible. Experiments looking towards the use of manganese indicate the possibility of a workable alloy with an elastic limit of about 55,000 pounds per square inch, but the field is wide and much of it is unexplored, therefore there is reason to hope for still greater improvement in metal for bridges.

Heat treatment can be applied only to members or materials which require no further fabrication. Heat-treated eye-bars with an elastic limit of 50,000 pounds per square inch have proved satisfactory in railway bridges, and others with an elastic limit of 75,000 pounds are economically used in highway structures. Heat treating is an old process of improving the quality of steel, but the results vary widely with the quality of the steel, the temperature employed and the uniformity of its application, the rapidity of cooling, and other factors. The pyrometer affords the means of controlling temperature, and the microscope discloses the structure of the metal, but even the most approved physical tests of the finished product do not always disclose the truth. The failure of the wire in the cables of the Mt. Hope Bay bridge and the Detroit River bridge is abundant evidence that caution and liberal preliminary use are desirable before new processes and materials are used in the principal parts of major structures.

The use of calcined clays which expand greatly in the burning and make a light but strong concrete aggregate has materially aided the economical use of concrete floors for highway structures. This clinker has not the wearing qualities of stone, therefore concrete made of it should not be exposed to traffic. But the saving of about 40

pounds per cubic foot of floor slab which it effects makes it desirable and generally economical for vertical lift spans and for long-span bridges.

No outstanding improvements have been made in the processes of fabrication. High-speed tool-steels have facilitated machining, particularly drilling, thus saving cost by encouraging the greater use of thicker metal. The rolling of H-sections and deep, broad-flanged I-beams has reduced the amount of shop work required. The use of the independent bent instead of continuous falsework and the development of the guyed traveler have facilitated erection. Many other improvements have been made in shop methods and shop tools, but they are only normal and do not merit special note.

So, in the design of bridges the advances have been gradual and normal, great in the aggregate but individually of but moderate importance, with the exceptions of the form and character of the movable bridge, the growth in the use of continuous structures, the development of alloys of high strength and (most important of all) the great increase in magnitude of span. As the motor vehicle has spread our cities over great areas, eliminated rural isolation, and in many other ways changed the whole manner of American living, so it has built a great system of highways which have been carried across impeding waterways by bridges unparalleled in number and in magnitude. In all this the part and the responsibility of the engineer are very great. He may well ponder the words of Ruskin:*

"Therefore, when we build, let us think that we build forever. Let it not be for present delight, nor for present use alone; let it be such work as our descendants will thank us for, and let us think, as we lay stone on stone, that a time is to come when those stones will be held sacred because our hands have touched them, and that men will say as they look upon the labour and wrought substance of them, 'See! this our fathers did for us.'"

*Seven Lamps of Architecture, by John Ruskin. Chapter 6.

DISCUSSION

C. S. Davis:* Mr. Harrington has so fully covered the field that I do not think there is anything left for me to say. I could enlarge a little on the Eads bridge. The Eads bridge was dedicated and opened to traffic July 4, 1874. In 1888 the railroad floor was completely renewed. In 1902 the top flanges of the railway stringers were renewed and the highway deck completely rebuilt. The highway deck has been renewed once since then. In 1902 it was found that 48 of the tubes in the main arches were quite badly rusted due to the brine occasioned by salting the highway deck, and it was necessary to reinforce these. Five pins, in pin joints, were found to be pretty badly corroded. These were repaired, without putting the bridge out of service. The bridge was subject to quite an amount of vibration, so at that time the old sway bracings were entirely removed and new sway bracings of a modern type put in.

I think the way in which the owners have taken care of this structure is largely responsible for its existence to-day. At one time it was condemned. That was previous to the reinforcing carried out in 1902. The reinforcement carried out at that time made the structure suitable for the heavier motive power and assured of very much extended life.

C. N. Haggart:† I wish in the first place to thank Mr. Harrington personally for the very interesting paper he has given us. He has given us a clear view of some of the present-day bridge problems and their solution and an idea of the progress which has been made in bridge work in the last three decades.

I was very much in sympathy with what Mr. Harrington said regarding the ferries across the rivers. Every time I cross this new bridge at Philadelphia I am reminded of my first experience in Philadelphia in the winter of 1917. I took the ferry across the river to Camden. When we got out to the middle of the river we were frozen up and a tug cut circles around us to break up the ice across to the other shore. It took about an hour to get across. The following summer I had occasion to drive down to the shore, which is a couple of hours' drive, and there was so much traffic I had to wait

*Consulting Engineer, Pittsburgh.
†Consulting Structural Engineer, Pittsburgh.

three or four hours to get on the ferry; so it must be a great blessing to the people of Philadelphia and vicinity and farther away to have this wonderful structure.

While, as Mr. Harrington says, there has not been any flash of inspiration in bridge designing in recent years, there has been a wonderful progress and it is interesting to learn something about it.

John Lyle Harrington: May I inquire whether the new bridges crossing the Allegheny River are considered in Pittsburgh to be suspension or cantilever bridges. It is, of course, a matter of definition.

T. J. Wilkerson:* I believe I should answer that question as I proposed the type of bridge used and am responsible for the design. Perhaps a brief statement covering the early studies as to the type of bridges to be built at the three crossings would be of interest.

Many sketches were made covering various types including simple trusses, tied arches, cantilevers, and ordinary suspension bridges. These sketches were submitted to the Art Commission for tentative approval. They preferred the suspension type, as it left the roadway overhead open and the side elevation gave the least obstruction to view.

The two suspension bridges at that time standing in Pittsburgh had been affected by the moving of an anchorage. On the North Side the Baltimore & Ohio Railroad tracks were between the river and a proper anchorage. On the South Side the Planning Commission proposes to construct a boulevard along the river bank and this may be either at bridge level or lower, and would be between shore and anchorage. Bearing these facts in mind it was thought desirable to design a structure with short approach spans and construct the main bridge between the shore piers as a unit having only vertical forces acting on the piers.

I can not conceive how any one can class the structure as anything but a suspension bridge, as there are no members to transfer the shear between the stiffening girder and the cable. It makes no difference how the horizontal pull of the cable is taken care of,

*Consulting Engineer, Beaver Falls, Pa.

whether it be by land anchorage or by the stiffening girder acting as a strut between the ends of the cable.

JOHN LYLE HARRINGTON: It is not a suspension bridge because there is no suspension. It is a unit.

T. J. WILKERSON: It is anchored at the ends.

JOHN LYLE HARRINGTON: It has no horizontal load.

T. J. WILKERSON: If you cut the cable in the middle of the main span, the bridge would collapse as there are no rigid connections between the cable and the stiffening girder to take shear, which would be required to make the structure act as a cantilever. The bridge, however, was erected as a cantilever by the use of erection diagonals to take the shear, and these were removed as soon as the cable and stiffening girder were connected up.

JOHN LYLE HARRINGTON: It seems to me to be a question of definition. I wanted to know how you considered it here.

T. J. WILKERSON: These bridges should be considered what they really are—that is, suspension bridges; they were designed as such.

JOHN LYLE HARRINGTON: But there is no suspension. The bridge itself is a unit. A suspension bridge superstructure is not a self-sustaining unit.

T. J. WILKERSON: The horizontal pull of the cable is taken by the stiffening girder acting as a strut between the end connections of the cable.

JOHN LYLE HARRINGTON: I understand the construction perfectly. It is all a question of definition.

T. J. WILKERSON: In the two bridges I have designed for Beaver County, crossing the Ohio River, one completed and the other

now being erected, I used heat-treated, carbon-steel eye-bars. The specifications require the full-size test-bars to have a yield-point of not less than 50,000 pounds per square inch, an ultimate strength of not less than 80,000 pounds per square inch, an elongation of eight per cent. in 18 feet, and a reduction of 35 per cent. All full-size tests made have shown results in excess of those specified.

All the heat-treated bars are tested. The bars made for full-size test were Brinell tested and their hardness numbers found. The bar was then tested and, when satisfactory, its results were used for determining the Brinell requirements for the other bars. Any bar that did not show the proper Brinell hardness number was again treated until it did show proper results. It has been found from thousands of tests that the Brinell hardness number bears a close relation to the ultimate strength of carbon steel, whether heat treated or annealed.

JOHN LYLE HARRINGTON: In that connection, I want to say that there is still a lot we do not know. That is thoroughly proved by the fact that in the Mount Hope and Detroit cases every known test was applied to the wire, but these did not disclose the facts.

In the wire ropes used in my own experience, the tests employed were those to which all the wire in rope drives and in all the vertical lift bridges have been subjected. The tests are severe. The usual tests for tensile strength, for elongation, for elastic limit, for reduction of area, etc., and in addition bending tests and torsion tests were all applied to these ropes. They did not show any fault in the material. Neither did anything appear which indicated that the breakages were continuous or that the time element figured in the matter. There is much we do not know and we do not know how we are going to find it out. We know that normal and usual tests will not reveal all the facts.

T. J. WILKERSON: I think there is a possible change of structure.

JOHN LYLE HARRINGTON: That there has been some change of structure in the wire seems highly probable. There has been some change in the formation which resulted in the breakage. What it is we do not know.

E. C. HARTMANN:* I should like to ask Mr. Harrington to what extent engineers are influenced by the corrosion and fatigue of metals in their selection of design stresses.

JOHN LYLE HARRINGTON: Engineers have always been fearful of using too thin material because of the presumption that the owner would neglect to maintain the structure. They have allowed a certain amount of thickness to take care of a certain amount of neglect, a procedure which is somewhat justified. Otherwise, engineers are not interested in the matter of corrosion, for all metals should be thoroughly protected. It is true, owners neglect their structures. I remember a few years ago a party for whom I was designing a bridge asked me to recommend a paint. The paint he had did not last any length of time. I said, "Go back and see when you bought the last paint that was used on any of your county bridges." He found the last purchase was fourteen years before. That is not unusual. None of these structures can live without maintenance. The idea was prevalent that concrete structures did not need maintenance. We now know that that is not true. They do require maintenance and they are pretty hard to maintain. But in the choice of stresses, reliance has been placed upon the quality of material. Results of tests and results in service form the best basis we can get for determining materials and stresses to be used.

In the determination of loads we have this eternal problem of impact to deal with. Investigations of railroad impacts have been very fully carried out. In highway impacts there are a good many conjectural elements. I remember a bridge engineer on the Union Pacific when I was designing a highway bridge for his company said to me, "Are you going under the presumption that there is a road roller factory at one end of the bridge and a continuous line of rollers using the bridge?" The road roller is now unimportant in comparison with the heavy truck. The impact is very high when there is a break in the pavement causing a drop of one or two inches. A break in a solid truck tire will cause a similar impact every time the wheel goes around. I have seen structures subjected to all kinds of punishment, many of them inexcusable.

*Research Engineer, Aluminum Co. of America, New Kensington, Pa.

Should the engineer design for gross lack of maintenance? That seems unreasonable, yet lack of maintenance leads to failure. We were called in to report upon the failure of a bridge at Dayton, Ohio, that caused us to marvel that it stood up as long as it did. To-day many highway bridges are carrying loads far in excess of anything that was likely to occur when the bridge was designed, but it seems doubtful that increase in loads will continue. Many states limit loads to those for which their principal roads and structures were designed, yet occasional heavier loads would do no harm, for the stresses employed may safely be exceeded for the occasional load. In dealing with old railroad bridges, every engineer has allowed stresses he would not think of employing in a new structure. Stresses up to 22,000 pounds per square inch in old railroad structures are not at all uncommon. There are specifications permitting stresses in old structures to run up to 26,000 pounds.

There is no such thing as fatigue of metals within normal stress limits. It is only when you pass normal stress limits that you have fatigue. In the tests by Professor Moore at the University of Illinois you find that the line of fracture due to repeated stresses becomes horizontal at a very few million applications. Down to 24,000 pounds you can apply the load without limit. Applications were made up to 10,000,000 without any evidence of deterioration when specimens were later subjected to microscopic tests and to the normal physical tests. There is a field below the elastic limit and above the safe limit of fatigue that is good for a certain amount of stress, not too often repeated, but sufficient repetition will cause slight modification in the structure and ultimate failure. Below that point, which is around 24,000 pounds in carbon steel, no amount of repetition of stress will cause failure.

F. S. MERRILL:* A previous speaker asked about adding metal to take care of corrosion. Our company has investigated a lot of bridges and viaducts in the steel plants around Pittsburgh and has found it decidedly worth while to put in good, heavy material at the piers. Base-plates and end stiffeners, particularly, rust out where dirt collects around them. Serious failures have been averted only by finding out these conditions in time and correcting them.

*Assistant to Division Engineer, American Bridge Co., Pittsburgh.

Mr. Harrington's paper refers to the question of economy of cantilever or continuous spans compared with simple spans. In very many cases the proper type to use depends on how the bridge is to be erected. In many cases we have to change the design of a bridge due to the fact that falsework could not be counted on certainly, either due to probable high water or ice during the time the span was to be erected, or to the necessity of keeping a clear opening for river traffic.

If a bridge has to be erected as a cantilever, and additional material furnished near the piers to do this, it is usually economical to leave this material in the bridge and make the finished structure a cantilever or continuous type.

J. F. LABOON, *Chairman:** I do not happen to be a bridge engineer, but I was wondering whether you would be willing to enlighten us as to your opinion as to the cause of the failure of the Quebec bridge.

JOHN LYLE HARRINGTON: For two years, 1905 and 1906, I was chief engineer and manager of the American Locomotive plant at Montreal. We had a bridge shop and locomotive shop. We had men competent for that work. One of these men afterwards became the secretary of the Quebec Bridge Commission and had a hand in the work from beginning to end. Unfortunately he has gone to his last reward. We talked many times of what happened to the bridge. So did a number of other engineers. We were fully convinced as to what was the trouble. We did not have to go outside of Pittsburgh to find out why the first bridge failed. The direct reason of failure was simply too much stress in the material. The direct stresses at the time of the failure were about 18,000 pounds per square inch in the bottom chords. The indirect stresses due to the fact that the secondary stresses had not been considered during the erection period were quite as great. There were over 36,000 pounds to the square inch in carbon steel, with inadequate bracing. The result was perfectly plain. These facts were determined by Paul Wolfel. In his judgment that was why it failed. In the case of the second failure, it seems certain that the casting on which the shoe rested slipped off the girder which supported it. As you well know, a truss has no strength unless it acts in the

*J. N. Chester Engineers, Pittsburgh.

plane. It did not act in the plane. The picture of the bridge, as it was falling, indicated that very clearly. Two of the other castings for a time carried double the normal load without any evidence of failure. They remained intact on the girders. There may be difference of opinion in regard to the matter, but in my mind it seems certain that the girder slipped from under the shoe. The center of the pin in the shoe and in the first link of the suspending chain were almost on the same level, hence there was little to prevent rotation.

F. R. SHUNTHILL:* I would like to ask what consideration engineers are giving to the vibration of bridges due to wind or live loads. What I have in mind is the question of vibration in itself rather than its effect in terms of stresses or physical properties of the material. Would it be feasible, for instance, to design a bridge so that the frequency of its members, or the members taken together, would be either above or below that of heavy vehicles running at normal speeds?

JOHN LYLE HARRINGTON: That is all lumped in with the impact allowances. The vibration stresses as such are not readily determinate and they are cared for by that allowance, as a great many other stresses are. You have a field where you are dealing with an elastic material of variable quality, but variable within narrow limits. Your loads are variable. The good material is somewhat variable, and your impacts are more variable. Your vibration stresses are variable. Nobody knows what your wind stresses are. Investigation by the Institution of Civil Engineers showed that the wind loads were decidedly less than those for which we are accustomed to design. Yet in the interest of safety we design for heavy wind loads because it is better to be safe than sorry. The effects of these uncertain stresses are all dumped into the impact stresses. We do not know just what they will be, but we make quite liberal allowance for them.

We stiffen trusses in a manner wholly foreign to the old designers. The old bridge over the Ohio River at Henderson has just the main members, and not a transverse sway brace in any truss except one. It stands, and it does its work, because some of the theoretically possible loads or combinations of them never occurred. Trains pass

*Engineer, Bureau of Bridges, Allegheny County, Pittsburgh.

over it at low speed, greatly reducing impact and vibration stresses and rendering it safe for modern traffic, though presumably at higher stresses than current practice would authorize.

Referring again to the question of fatigue of materials, our Interstate Commerce Commission has a remarkable theory that a bridge superstructure deteriorates 1/70 each year. Each bridge is worth 1/70 less each year and a bridge that has been up 10 years is worth 60/70 of what it was worth when it started, though the loads may be the same, the material may be the same, the bridge may be identical in every respect. For rate-making purposes the Commission has depreciated according to a straight-line formula, which is wholly irrational, yet hundreds of bridges on thousands of miles of roads are evaluated on that basis. That is on the theory that these bridges will have to be taken out at the end of 70 years. We know that the majority of bridges are taken out because of obsolescence and not because of depreciation of material.

J. HAMMOND SMITH:* I would like to ask Mr. Harrington's opinion regarding the flexibility of structures in cases where higher unit stresses are used. As we increase the range of stress in any structure, the extent of distortion or deflection is generally increased in proportion. In riveted trusses, the secondary stresses would be increased accordingly because the angles between the members would vary over wider ranges, thus introducing greater flexural stresses in the members.

JOHN LYLE HARRINGTON: That again is a matter of debate and opinion. That problem arose on the bridges for the Pennsylvania and the New York Central which stand side by side—one of nickel steel and one of carbon steel. The Pennsylvania objected to nickel steel because of the greater deflection in the trusses. The New York Central did not take exception to that. As a matter of fact it does not make any difference as long as the stresses are within safe limits. If the deflection meant stress out of proportion to the material, it would be a wholly different matter.

In examining an existing railroad bridge, I want to figure stresses carefully and I want to see how it acts laterally as much as,

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if not more than, vertically. Calculation of stresses will give me what the material is being subjected to, but the lateral deflection particularly will tell me a good deal about the qualities of its design. One of the things that made railroad engineers turn from pin-connected trusses to riveted trusses was the greater rigidity of the latter, especially when overloaded. I had occasion to examine a riveted truss span over the Minnesota River that ought by all the rules to have failed. The members did not come to a center at joints and the secondary stresses were large, but it was doing its work without distress; whereas if it had been a pin-connected structure subject to loose-jointed movements it would not have been there. You can not figure old elevated railroads of New York without shock, but they stand.

J. F. Laboon, *Chairman*: Is there any further discussion? If not, on behalf of the Society I wish to thank Mr. Harrington sincerely for his very interesting paper, and to invite him to come back to the afternoon meeting.

BRIDGE ARCHITECTURE*

By Wilbur J. Watson†

It may seem strange that an engineer should presume to talk on the subject of bridge architecture, as engineers are popularly not supposed to be particularly interested in that feature of bridge construction. The popular conception of an engineer is a man who deals only with the exact sciences, particularly with mathematics. It has been my belief for many years that this conception of the engineer is not what it should be and that all engineers having to do with the design of structures should either be trained in the principles of architecture or should collaborate with architects in the design of their structures.

Several years ago I published a book with the title of "Bridge Architecture"‡ and immediately many of my friends said, "We thought you were an engineer. What do you know of art or architecture?" My answer to them is that unless the engineer, whose technical training best fits him to have responsible charge of the design and construction of bridges, knows something of the underlying principles of architecture we can not obtain the degree of attention to esthetics, or pleasing appearance, which the time, or rather an enlightened public, now demands. Granted that the engineer is to retain responsible charge of the design and construction of bridges, it is not sufficient that he should collaborate with an architect who, in his turn, has had no training in engineering principles. The result of such collaboration in the past has usually been that the architect simply ornaments the work of the engineer with applied decoration which violates the basic principle of good architectural design.

In this connection, allow me to quote the following from Emerson: "The beautiful rests on the foundations of the necessary." This will be the text of my discourse. Our lesson is from a recent editorial in the *Engineering News-Record*, "A structure should express its function, as a whole and in its parts, in order that it may seem what it is and not like something else." To obtain these results, I believe that it is absolutely essential that the bridge engineer must himself

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†Wilbur Watson and Associates, Cleveland.
‡Bridge Architecture. 288 p. 1927. Helburn, New York.

have a certain amount of artistic training, even though he continues to collaborate with architects in the design of his work.

Hitherto, there has been an almost exclusive insistence upon the science of bridge design in the training of bridge engineers, with the result that structures designed by such engineers, without the collaboration of trained architects, are usually devoid of art, although marvels of science. On the other hand, when the design of bridges has been entrusted to architects alone, or in responsible capacity, science has usually been sadly abused, because not understood. It would seem to be almost self-evident that the construction of structures such as bridges, which require the highest scientific skill, should have the responsibility for their design and execution placed in the hands of engineers, who alone have the proper technical training to solve the scientific problems involved as well as the practical problems, and that the architect collaborating with the engineer should do so in a consulting capacity. As long as the community was satisfied with bridges that were frankly and only utilitarian, and as cheap as could be built and serve the purpose, usually temporary and built of materials that were not lasting, the practical-minded engineer was all that was required.

But times have changed. The average citizen is being educated to the value of art in everything, not just beautiful pictures to hang on one's wall, but art that puts pleasure in parks, gardens, the house we live in, the clothing we wear, household utensils, and in every structure we build, including bridges. We, as a people, are simply becoming more civilized. If engineers persist in building structures that do not meet this modern demand, there is danger that public officials, always sensitive to the demands of the people, will place the responsible charge of the design of bridges in the hands of architects instead of engineers, which is not as it should be. However, we can not educate engineers in the principles of art, or persuade them to consult with architects in the design of their work, unless we can first interest them in the subject, and we are forced to admit that many engineers are simply not at all interested in things which are artistic or of pleasing appearance.

In this connection, it may be of interest to state that the sales of the book on "Bridge Architecture" have been largely to architects, who seem to have a much keener interest in the subject than engineers,

although this, perhaps, should be qualified by the statement that it applies to the American sales only. The foreign sales have been largely to engineers. I recently took the trouble to look over the list of sales with the publishers in order to ascertain where the demand for the volume was coming from in order to determine the parties who were most interested in the subject. It is my object to-day to stimulate, to as great an extent as I can, the interest of engineers in the art of bridge design and I know of no better place to start than here in Pittsburgh where the material for so many of the greatest bridges of the world is manufactured and where so much good work is being done in bridge design for your own use.

The *art* of bridge design is not, as I see it, purely a decorative art. It is rather a knowledge, or a feeling of propriety—an educated sense of proportion, of pleasing outlines and of color, with or without decoration of any kind, as good taste dictates. As regards appropriateness, bridges should be in keeping with their surroundings.

Recently, I received from the American Institute of Steel Construction a brochure illustrating some prize designs—the result of a competition conducted by them through the Beaux-Arts Institute of Design. The first prize was awarded to a design that violates utterly, to my mind, the basic principles of bridge architecture. It is a deck steel structure indicating an arrangement of truss members which is most unscientific and strikes the trained bridge engineer very disagreeably. The second prize design is a little better as regards arrangement of truss members, but indicates cast-iron decoration applied to these members. The third prize design shows a structure which does conform to good engineering principles.

It is my opinion that the publication of this booklet and its circulation among engineers will do far more harm than good, in that it corroborates the already existing prejudice on the part of engineers against the employment of architects as consultants in bridge design.

Just now there is considerable criticism of the design of the new Hudson River bridge, for which a prominent architect has been engaged to assist the engineers of the Port of New York Authority. This architect is incasing the steel towers of the bridge in masonry, which no longer expresses the function of such a tower. When the Brooklyn bridge was built across the East River at New York, the function of the tower was best expressed by masonry towers, but that

is no longer the case, and it is my opinion that it would have been far better to leave the steel for these towers exposed, modifying the design somewhat, perhaps, to express its purpose more fully.

I have selected a few illustrations of recent work, largely Pittsburgh work, which, I hope, will emphasize the remarks which I have been making. In this connection, I wish to express my pleasure on reading and looking over the illustrations of a book on "The Bridges of Pittsburgh"* written by Joseph White of the Department of Public Works of Allegheny County and M. W. von Bernewitz, containing illustrations of many of your most beautiful structures here in Pittsburgh.

I also wish to thank the officers of the American Bridge Company, the McClintic-Marshall Construction Company, and the Port of New York Authority for photographs from which the lantern slides used with this paper have been prepared.

In conclusion, I quote from the translated writings of Leonardo da Vinci, who lived in the fifteenth century and who has been called the "Founder of Engineering," although he was artist, architect, and scientist as well—"Experience shows the way to practice; science is the guide to art."

DISCUSSION

J. F. Laboon, *Chairman*:† We have the foundations built and the bridge designed and we want a little architecture. Will somebody start it?

D. C. Seeley:‡ We students do not have the opportunity of observing things from as practical a standpoint as senior members of the Society, and our views at present are mostly those which we gather from our studies and lectures.

Last spring we had a lecture at school by Mr. Amman, who served on the construction of the Hudson River bridge. He told us that the towers at the entrance to the bridge were made of concrete in order that they might conform to the massive nature of the Palisades, and thus improve the bridge from an esthetic standpoint.

*The Bridges of Pittsburgh. 113 p. 1928. Cramer, Pittsburgh.

†J. N. Chester Engineers, Pittsburgh.

‡Student, Carnegie Institute of Technology, Pittsburgh.

WILBUR J. WATSON: I think that is a matter of individual taste. Unfortunately art and architecture are largely matters of individual taste. I have been told that masonry was adopted to inclose the towers in order to harmonize with the masonry of the anchorage piers. The side view from the river scarcely shows the anchorage piers. Looking at the bridge from the shore adjacent to it either up or down stream you will see them both at the same time. I would have preferred the other method, using exposed steel towers.

C. S. DAVIS:* I have listened, with much interest, to the address of Mr. Watson and wish to compliment him on having so clearly and concisely stated the problems confronting the bridge engineer.

For emphasis it may be well to repeat some extracts from his address and to show their relation to local conditions:

> "All engineers having to do with the design of structures should either be trained in the principles of architecture or should collaborate with architects in the design of their structures."
>
> "A structure should express its function, as a whole and in its parts, in order that it may seem what it is and not like something else."
>
> "It is absolutely essential that the bridge engineer must himself have a certain amount of artistic training."

Mr. Watson has called attention to what may be expected when the engineer fails persistently to adopt the principles which have just been quoted. This may be well illustrated locally.

For some time previous to starting an extensive bridge building program by Allegheny County, several architects led by that able and noted Director of the Department of Fine Arts, of the Carnegie Institute, Mr. John W. Beatty, in order to secure better and more beautiful bridges, induced the county commissioners to place the design and construction of two bridges in complete charge of architects—the Washington Crossing and the Sixteenth Street bridges over the Allegheny River.

In the case of the Washington Crossing bridge there was earnest co-operation between the architect and the engineer to the end that the finished structure had both architectural and engineering merit and did not violate the principles of good design.

*Consulting Engineer, Pittsburgh.

The original design for the Sixteenth Street bridge had much merit but on account of navigation requirements and for other reasons the design was altered with the result that the finished bridge is not free from conflict with the principles of good bridge design. The relative proportions of the center and side spans are not entirely satisfactory. The spans, being of simple truss construction, having the appearance of arches, call for massive pier construction instead of the slender piers at the ends of the center span, as built; clearly a violation of the principles of good bridge design. In the original design massive pylons were placed at the ends of the center span and were in harmony with the balance of the structure. For some reason these pylons were transferred to the shore ends of the bridge with disastrous results in its general appearance.

Even though the Sixth Street bridge over the Allegheny River received the award of the American Institute of Steel Construction as the most beautiful bridge built in 1928, I have the temerity to say that this bridge and those at Seventh Street and Ninth Street violate the principles of good bridge design. They are fictitious structures, having the appearance of suspension bridges but in reality being bridges of the cantilever type. Suspension bridges call for massive anchorages which are missing in these structures. Small and slender pylons, lacking all appearance of mass, are all that are apparent as anchorages for the massive cables or tension chords of the trusses. The lines of the portals, which are of massive construction, indicate weakness but these are of minor consideration as compared with the fictitious character of these bridges.

There is another recent example of the violation of the principles of good bridge design—one that has been severely criticized by many persons not trained in engineering or architecture. This structure reminds me of an abortive attempt to create a new and monstrous type of structure. I will leave it to you to answer the question as to what bridge this is.

I thoroughly agree with Mr. Watson in his opinion of the competition conducted by the American Institute of Steel Construction through the Beaux-Arts Institute. The purpose is commendable but the results are ludicrous.

T. J. WILKERSON:* We were hampered by the Art Commission and the architects. The engineers had to submit a design that they would pass.

J. F. LABOON, *Chairman:* I think this meeting will go down in history as discussion of a question as to whether they are suspension or cantilever bridges.

T. J. WILKERSON: They were designed by the suspension theory. The main roadway is suspended from a cable.

C. S. DAVIS: A few days ago I was told something that will possibly clear up the whole situation. I was told that all members above the floor were always in tension and therefore it was a suspension bridge.

E. BJORKLUND, JR.:† The speaker referred to co-operation between architects and engineers. I would like to ask how that may be accomplished.

WILBUR J. WATSON: The idea I tried to convey was that two men of radically different training can not collaborate satisfactorily unless each one has to a certain extent the viewpoint of the other. If they occupy absolutely different fields they may have no appreciation of each other's province and can not properly collaborate because there is no mutual sympathy. It is a psychological problem rather than a scientific one.

E. BJORKLUND, JR.: I realize that at present the co-operation is not as great as is desirable and I would like to know what Mr. Watson thinks can be done to increase the co-operation between architects and engineers.

WILBUR J. WATSON: I think it should be taught in the schools. I am more or less familiar with educational methods in both engineering and architecture, and I think the engineer should be taught more of the basic principles of art and the architect should be taught more of the basic principles of science.

*Consulting Engineer, Beaver Falls, Pa.
†Student, Carnegie Institute of Technology, Pittsburgh.

J. L. HARRINGTON:* The question of whether the engineer's or the architect's views should prevail in matters of appearance is sometimes very difficult to settle. The architect's opinion prevails in the Washington Memorial bridge at Washington, now under construction. One of the most expert firms in New York fixed the form of the arches between the center movable span and the ends. The engineers could find no material that would sustain the stresses that that form involved. Of course science had to have its way and the form had to be modified.

It is true there is a marked and continuing difference between architects and engineers on bridge design. I see no possible way to eliminate that difference, because it is fundamental to the two professions. One is a closed profession, with all the assurance of the members of a closed profession. The other is an open profession, where any man's opinion goes and any one is entitled to express his opinion. There are times, of course, when the architect and the engineer can get together and co-operate in harmony, but they are exceptional, and there is always the greatest question whether there will be close co-operation between architect and engineer.

I went to see one of your prize plans in Pittsburgh when it was in the inceptive stage, when the architect was chosen to insure the beauty of the structure, and I will say frankly that the structure would have fallen down had it been built as that particular drawing showed. The architect happens to be one of my school friends and there is no criticism of him as an architect. He simply did not know bridge design, and the structure simply could not have stood had not some engineer taken the design in hand.

I will agree with Mr. Watson, the engineer ought to have his taste cultivated, and the architect ought to have more science, and this ought to be done as far as may be done, in the schools, if you can find time for it. But the engineering student has more than he can accomplish now and I do not know what he is going to do when you add to his burdens. All of us ought to do a great deal more than we do, but I do not know how to insure that we do it. All of us ought to have a great deal more training in architectural taste, but the time is not available for it. How we are going to bring about improvement under present conditions; how the closed profession can be

*Harrington and Cortelyou, Kansas City, Mo.

induced to co-operate sincerely with the open profession—an open profession that can not easily co-operate within itself—I do not know.

S. C. HULSE:* Nobody seems to have mentioned the Bear Mountain bridge.

WILBUR J. WATSON: That was a problem of decoration.

S. C. HULSE: It is a matter of decoration that interests me. When I first saw that bridge it was not quite completed. You remember that on one bank of the Hudson at this point there is a beautiful mountain of almost naked rock of many lovely colors and on the opposite bank the hills are heavily forested. There are steamboats on the river. There is something of a holiday air about the place, especially on Sundays. As I first saw the bridge, the main cables were a brilliant red and the rest of the structure had been painted black. Of course the cables were still in their priming coat but they stood out from the rest of the black structure and were emphasized and certainly did not, while adding to the beauty of the bridge and its setting, detract from the dignity of the great span. I was at the time in the company of a distinguished landscape painter from New York and his comment was, "Well, for once, some Americans have not been afraid to be a little gay about a serious matter. Do you suppose they will have sense enough to leave it that way?" The next time we saw the bridge the cables were black and it looked just like any other bridge—the brightness was gone.

P. W. PRICE:† I remember very distinctly talking with one of the engineers connected with the design and construction of the Philadelphia-Camden bridge. In this case a well known architect was employed by the Bridge Commission in a consulting capacity. It was so arranged that final decisions affecting architectural treatment would always rest with the chief engineer who was also Chairman of the Board of Engineers for the Delaware River Bridge Joint Commission.

Their first problem was that of type and questions of general design affecting the appearance of the bridge as a whole. When these

*District Manager, Foundation Co., Pittsburgh.

†Assistant Construction Engineer, Bureau of Bridges, Department of Public Works, Allegheny County, Pittsburgh.

matters were settled to the satisfaction of the Commission and with the assistance of the architect, many questions arose as to proper design of important details affecting both structural design and architectural treatment. One case in particular caused considerable discussion. This was the form of bracing to be used between the posts of the main towers. The architect favored one design, but the engineers were strongly in favor of something more typical of good engineering practice in steel structures. The final decision was made by Mr. Modjeski after giving due consideration to all designs submitted by both the engineers and the architect.

This represents what, to my mind, is the proper function of an architect in bridge design. His advice and co-operation should always be available on all types of bridges both large and small, where beauty of general lines and in details is sought, but his function should always be of secondary importance to that of the engineer who is responsible for the job as a whole. The general type of structure should almost always be left to the engineer, especially if the cost of the structure is in any way limited or if other special conditions such as horizontal and vertical clearances, or permissible methods of erection are so fixed that they practically determine the type that can be considered for a given location.

In many cases the best service that an architect can render is confined largely to a study of details relating to a pleasing combination of structural steel members, both as to beauty and in general lines and in details. This applies also to lines and details of the masonry substructure and approaches to a steel bridge. When the design is carried out wholly in reinforced concrete the same principles apply. It is more the function of the architect to suggest pleasing proportions of line and mass according to fundamental principles of good architecture than to spend a lot of time and money on special architectural additions to the general design which are often relatively unimportant and often, in fact, unnecessary and even detrimental to the appearance of the bridge as a whole. If these so called "decorations" are added by architects to a structure which is fundamentally wrong from the standpoint of beauty, the effect is even worse. In other words, the architect should have been consulted during the period of general design in an effort to secure the most pleasing structure as a whole. Then the matter of how much or how

little "decoration" is added is often a matter of cost or good taste, or both. Generally speaking, the less ornamentation added to a structure which already well expresses its function and is pleasing to the eye, the better will be the effect as a whole.

I am a great believer in careful attention to the design of details both in structural steel and masonry in order to obtain a pleasing appearance. This matter is often overlooked in bridge design. Many times it is not a matter of cost alone that determines between good design and poor design in the important matter of securing a pleasing structure; and that is what both engineers and architects should strive to attain within the physical and financial limitations which are nearly always present and always to some extent affect design.

While discussing bridge architecture and the relation of engineers and architects engaged on such work it might be well to state that the practice of the Department of Public Works of Allegheny County, with which I am connected, is now substantially as outlined above. There is a Bureau of Architecture in charge of a competent registered architect and this bureau is called on for advice and assistance in the study of our more important bridges. The County Architect and the Chief Engineer of the Bureau of Bridges report to the Director of the Department of Public Works.

In any case where there might be a decided difference of opinion between these two bureaus involving questions of type or detailed design, the matter would be referred to the Director for decision. The Director of this department is, and I hope always will be, an engineer whose good judgment can be trusted to adopt for our future bridges such designs as will compare favorably with those recently built by Allegheny County. One of our recent bridges has received national recognition and award of merit as the most beautiful steel bridge built during the year 1928.

C. N. Haggart:* While we are getting money to improve the appearance of the bridge, I believe we should also endeavor to obtain the money to improve the immediate surroundings of a bridge.

Very often bridges that in themselves are pleasing to the eye, have their beauty somewhat marred by the unsightly appearance of the vicinity of the approaches. The river banks or the water edges

*Consulting Structural Engineer, Pittsburgh.

may be unsightly or the ground around the approach to the bridge may be littered with debris or refuse. The ground at approaches may also be uneven and should be improved by grading and smoothing the slopes. Trees and shrubbery might likewise be planted to improve the landscape.

The extent to which such improvement might be carried out, would depend on the size and location of the bridge, but in each case, I believe, it should be the duty of every bridge engineer to endeavor to get money for such purposes and to cultivate public opinion to help along such improvements.

NORMAN F. BROWN:* In the open discussion following the presentation of this paper, Mr. C. S. Davis, a local engineer, voiced before this Society certain misleading statements concerning the design of the Sixth Street and Point bridges, which I, as Director of the Department of Public Works of Allegheny County, feel should be refuted, in all justice to the engineers of the Bridge Department who have worked so industriously and conscientiously on these structures; and who, in my opinion, deserve considerable credit for their efforts. I submit herewith letters from some of the responsible heads of departments in answer to these criticisms.

As for me, I should like to quote the remarks of Mr. Davis:

"Even though the Sixth Street bridge over the Allegheny River received the award of the American Institute of Steel Construction as being the most beautiful bridge built in 1928, I have the temerity to say that this bridge and those at Seventh Street and Ninth Street violate the principles of good bridge design. They are fictitious structures, having the appearance of suspension bridges but in reality being bridges of the cantilever type. Suspension bridges call for massive anchorages, which are missing in these structures. Small and slender pylons, lacking all appearance of mass, are all that are apparent as anchorages for the massive cables or tension chords of the trusses. The lines of the portals, which are of massive construction, indicate weakness but these are of minor consideration as compared with the fictitious character of these bridges.

There is another recent example of the violation of the principle of good bridge design—one that has been severely criticized by many persons not trained in engineering or architecture. This structure reminds me of an abortive attempt to create a new and monstrous type of structure. I will leave it to you to answer the question as to what bridge this is."

*Director, Department of Public Works of Allegheny County, Pittsburgh.

It is deplorable, almost to the extent of sympathy, that these expressions, so apparently misleading, should have gone unchallenged by others than engineers of our own Department of Public Works. The very definition of a suspension bridge is inherent in the design of the Sixth Street, Seventh Street, and Ninth Street bridges, and is substantiated and exemplified in the architecture and use of the materials of construction. These structures are truly suspension bridges, scientifically correct from an engineering standpoint, and they architecturally exemplify the intended purpose of the structures and the functioning of the various members.

The Point bridge is a cantilever structure and is in reality a very successful creation of a type of bridge primarily intended not only to produce an economic structure, but also to be in keeping with the architectural precedent established by the existing Manchester bridge. Much study was given to the architectural appearance of this bridge by the Pittsburgh Art Commission and our County Department of Architecture, with the idea of constructing a bridge in harmony with the Manchester bridge, and not considering it alone or as an individual structure.

It is consoling to note, however, that the adverse expressions relating to these bridges came entirely from an individual, voiced as personal expressions only and entirely without substantiating facts of his own or without any supporting expressions of the professional engineering talent in attendance at this meeting.

Herewith are the statements of three bridge engineers of this department. These three engineers represent the type, design, and execution of these bridges and their statements should be of paramount importance when engineering design and construction are considered.

As to architecture, I would call the attention of the Society to the fact that the Department of Public Works maintains within its organization a well established Bureau of Architecture, which functions in co-operation with the Bureau of Bridges in the design and lay-out of all County bridges. While I do not believe that the engineers of this Society have ever felt that these bridges "violate the principles of good design," as expressed by Mr. Davis, I do hold that such radical expressions are not conducive to the best intended purpose of the Society, and, consequently, should be eradicated. I there-

fore suggest that this communication be incorporated with the regular discussion of Mr. Watson's paper.

In conclusion, I offer the files, drawings, design calculations and other data covering these structures for the inspection of the Society or individual engineers interested in the subject.

T. J. WILKERSON:* Mr. Davis, in his discussion, states that the bridges at Sixth, Seventh and Ninth streets are "fictitious structures, having the appearance of suspension bridges but in reality being bridges of the cantilever type." Had Mr. Davis taken the trouble to examine these structures carefully, it is not likely he would have made such an error.

Cantilever bridges are not built as three continuous spans over four supports in a unit, such as these spans. Cantilever spans must be provided with web members capable of transferring diagonal shear between the chords. These bridges have no such members. All the web members are vertical hangers capable of taking vertical loads only. Furthermore, were they of the cantilever type, having the end spans anchored to the piers to resist reaction and uplift and being a unit without joints to permit vertical rotation, the cable could be severed at the center of the central span without the structure being weakened, which is not the case with these bridges. If they were not what they appear (true suspension bridges) they would come nearer to complying with the requirements of continuous girder over four supports.

Mr. Davis contends, because there are no massive visible masonry anchorages at the visible termination of the cables, that they violate the requirements of a suspension bridge. It is well that every one does not agree with him; if they did, progress in new types of bridge architecture would be very much retarded.

The question as to what constitutes a suspension bridge is very well answered by Merriman and Jacoby† in their historical notes on suspension bridges in which they state that the first true suspension bridge in this country was erected by James Finley in 1801 across Jacobs Creek near Greensburg, Pa., and describe it as having the roadway nearly horizontal, and hung from the chains by vertical rods,

*Consulting Engineer, Beaver Falls, Pa.

†Text-book on Roofs and Bridges, pt. 4, Ed. 3, 1907, p. 122.

while the chains themselves passed over the towers and by means of backstays were anchored to the rock, only that part between the towers being suspended from the cables.

It is therefore evident that any structure depending for its carrying capacity upon a cable or eye-bar chain suspended between towers from which by vertical suspenders it carries the loads—such as stiffening truss or girder, floor system and live loads—is truly a suspension bridge, regardless of how the cables are anchored against their horizontal pull.

George S. Richardson:* Mr. Harrington and Mr. Davis referred to the Allegheny River bridges as being of the cantilever type. As these gentlemen state, the classification is a matter of definition, but as a matter of common-sense each type must be defined in such a manner that the name reveals the principal characteristics of the structure.

Take the Sixth Street bridge as an example. The principal elements of this structure are as follows:

1. The main carrying member is an eye-bar chain having the usual form of cable or chain for the suspension bridge and supported at the main piers by steel towers.
2. The floor system is suspended from this chain by hangers.
3. The system is stiffened by a girder continuous for the three spans of the bridge.
4. The chain pull is resisted by an anchorage taking the vertical component, with the horizontal component carried by the stiffening girder.

If these elements are compared with those of the regular type of suspension bridge with continuous stiffening girder, they are found to be exactly the same with the one exception that the horizontal component of the chain pull is not carried into the anchorage. By a common-sense definition it must be considered a modified form of suspension bridge. A great many engineers have defined this type as a self-anchored suspension bridge. This term at once reveals the characteristics of the structure.

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What are the elements of the cantilever type? In its simplest typical form, they are as follows:

1. The main carrying member is a truss or girder.
2. From each anchor arm forming the end spans, a cantilever arm projects out from the main pier supporting a suspended span.
3. The cantilever arms and suspended spans are joined by hinges which resist shear but do not resist moment.
4. The vertical uplift at the ends of the structure is resisted by an anchorage.

Considering the possible modified forms, it is found that there are numerous arrangements of spans and the above is only the usual form. In the three-span lay-out, the suspended span may be omitted but one hinge must be retained or the structure becomes a continuous truss or girder. The center span may be made an anchor span, in which case there will be a cantilever arm and a suspended span in each end span. With this arrangement of spans, it is possible that no anchorage will be required, and in the first form no anchorage will be required if the anchor arms are exceptionally long. The anchorage is not an essential element of the cantilever type of construction.

The Sixth Street bridge, by a common-sense definition, is not a cantilever. The main carrying member is an eye-bar chain—not a truss or girder. It does not have a system of web members to resist shear. It does not have a hinged joint in the main span, as the cantilever without suspended span would have, or two such joints as the simplest form of cantilever would have. It has only one point in common with the usual cantilever form—an anchorage to take a vertical uplift—and, as pointed out, such an anchorage is not an essential element of cantilever construction and is not necessary with certain arrangements of spans. To call this bridge a cantilever is to give it a name which is completely misleading.

A. D. NUTTER:* Mr. C. S. Davis says that the three new bridges over the Allegheny River at Pittsburgh "are fictitious structures, having the appearance of suspension bridges but in reality being bridges of the cantilever type."

*Engineer of Bridge Design, Allegheny County, Pittsburgh.

The claim that they are in reality bridges of the cantilever type is rather astounding. His definition of a suspension bridge must be such as to exclude the Sixth Street bridge type, but I believe there are very few bridge engineers who will not agree with the dictionary (Webster's) definition that a suspension bridge is "A bridge which has its roadway suspended usually by vertical rods from a freely supported cable or cables." This expresses fully the essential characteristic of a suspension bridge—that is, a suspended roadway on a freely supported cable; the matter of anchorage, whether it be external or internal, or the presence of stiffening trusses or girders, is not necessary to define this type.

Accepting now this common-sense idea and definition of a suspension bridge, there should be no question that the Sixth Street bridge fulfils this requirement. The floor is suspended directly from freely supported cables which transfer practically the whole load to the supports. Surely this is not after the manner of cantilevers.

The statement that they are fictitious structures requires little more to be said for its refutation. It has been shown that they are suspension structures by a common-sense and generally accepted definition. The only change from the typical form consists in anchoring the cables to the stiffening system instead of an external support and this has not changed the type of the structure from suspension to something else; it has merely introduced the idea of resisting the horizontal component of the cable reaction within the structure itself between the ends of the cable. This is a modification of the typical form and has been named "self anchored," as it very aptly describes the construction and differentiates it from the usual form.

Suspension bridges do not necessarily call for visible massive anchorages; in fact, the anchorage masonry need be no more massive than might be used for a simple span. This is particularly well shown in W. Tierney Clark's Budapest suspension bridge. The self-anchored type could be substituted between his anchorages, they serving in the latter case, not as anchorages, but simply as filled abutments.

If the short spans at the ends of the Allegheny River bridges were not required for intended future developments, I doubt very much whether there would have been any criticism on anchorages. Massive anchorages are not required for a suspension bridge having a channel clearance of approximately only fifty feet. Since there is

nothing but a vertical reaction at the ends of the cables to be provided for by the masonry, the pylons, if anything but slender, would be fictitious.

The charge that the self-anchored suspension bridge is a cantilever bridge has been made apparently with little thought having been given to the internal stresses and reactions of the two types. There is no similarity between the two; there are no points in common which should cause one to be mistaken for the other.

In a cantilever structure, the loads are carried to the supports by the main trusses or girders through the action of shear, and the reactions are vertical; in the suspension bridge and the self-anchored suspension bridge, the loads are carried to the supports by tension in the cable, and the end reactions must have horizontal components and may not (but usually do) have vertical components.

Consider a typical cantilever structure consisting of two anchor spans, two cantilever spans, and a suspended span using the same supports as the Sixth Street suspension bridge. Now pass a plane cutting all members in one anchor span; the other anchor and cantilever spans stand; cut one cantilever span, all other spans excepting the suspended span and the other portion of the cut span stand; cut the suspended span, all other spans stand, stability alone being considered in each case. Pass a plane cutting all members of the typical or self-anchored suspension span at any point and the whole structure collapses. There is no semblance of cantilever bridge action, thus showing the dissimilarity of the two types. Furthermore, the methods of stress determination are entirely different; if one were acquainted only with the stress calculations for cantilever bridges a start would never be made in the case of the self-anchored suspension bridge.

The criticisms previously referred to have evidently been made without a complete understanding of the nature of the structure and can hardly be considered instructive or constructive, which, after all, is the essence of true discussion.

MECHANICAL EQUIPMENT FOR THE DAVISON COKE AND IRON COMPANY, NEVILLE ISLAND, PA.*

By G. E. Dignan†

This paper will attempt to show the general outline of the new plant now under construction by the Davison Coke and Iron Company on Neville Island, Pittsburgh, and to give a general, but necessarily brief, description of the mechanical equipment for the combined plant operation.

There will be a battery of coke-ovens, new cement plant, new power and steam generating equipment, and considerable changes in the present blast-furnace plant.

The cement plant will consist of two kilns, 10 by 175 feet. The present capacity will be 3000 barrels per 24 hours, with provision for a third kiln, with necessary apparatus for an ultimate capacity of 4500 barrels.

The coke-oven battery will consist of 35 Koppers Becker type ovens, with an ultimate capacity of 105 ovens and provision for complete recovery of by-products.

The present 600-ton blast-furnace will be operated as a merchant furnace and provision made for an additional blast-furnace.

The old vertical blowing engines, 14 vertical Cahill boilers, two 500-kilowatt reciprocating-engine-driven generators, the old reciprocating pumps, etc., have all been scrapped. The present blowing-engine house will be used for the new blowers, new electrical generating equipment, water-softening equipment, boiler feed-pumps, booster pumps, air-compressors, vacuum pumps and turbine auxiliaries. The present boiler house will be bricked in to house the new steam-generating equipment and machine-shop. The pump-house will contain the new main water-supply pumps and the switch panels for the coke-ovens.

The coke-ovens will furnish coke to the blast-furnace and domestic trade and coke braize to the direct-fired boilers. It will supply

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†Chief Engineer, Davison Coke and Iron Co., Pittsburgh.

gas for public utility purposes, with connections to the cement plant for firing the kilns, and will supply a full line of by-products.

The blast-furnace will produce merchant pig-iron, blast-furnace gas to the direct-fired boilers, and granulated slag for the cement-mill. The cement-mill will furnish waste heat for steam generation.

The present ore-storage yard will be utilized for the storage of ore and limestone for the blast-furnace; coal for the coke-ovens; and limestone, clay, and blast-furnace slag for the cement plant, thus concentrating the handling and storage of all raw materials in one place. Material handling has been designed to minimize yard handling, the coal being handled by belt conveyors from the river unloader to the coal-bin at the oven, and coke by belt conveyors from the screening station to the furnace bins. On account of the pig-casting machine being located in the furnace cast house, there will be no switching of hot metal with its attendant scrap loss. All outgoing material is loaded on gravity tracks with ample room for supply of empty cars for loading.

The present steam-driven car dumper will be rebuilt and driven with direct-current motors, with capacity for unloading 14 cars an hour. Ore, limestone, clay or slag will be delivered in standard railroad cars to the dumper, and loaded in a 60-ton transfer car, which can discharge into a grab pit the full length of the runway of the ore bridge. The transfer car operates also to the coal unloader at the river, so that coal or limestone can be delivered by barge and placed in the storage yard.

A new ore bridge is now under construction by the Dravo Construction Company. This bridge will span 285 feet between supports with a 35-foot overhang on the furnace bin end of the bridge.

Bridge travel is with independent drive on each set of trucks and is designed for a speed of 75 feet a minute. The trolley speed will be 650 feet a minute, and the hoist 195 feet a minute. The grab-bucket is of five tons capacity, or at the rate of 300 tons an hour. All motors are 240-volt direct current, all with magnetic control. There will be two motor-driven rail clamps on each leg, interlocked with bridge travel control. The operator must keep his foot on a push-button while bridge motors are running.

The ore bridge handles materials from unloading point to storage, thence to two cars for filling the stock bin. These cars operate the full

length of the blast-furnace stock house and over mills for raw grinding of cement.

The stock bin can also be filled direct from standard railroad cars which operate the full length of the bins and the raw grinding department of the cement-mill.

A new river dock, 100 feet long, is being installed. On this dock an electrically driven crane is installed to unload limestone or coal. The crane fills a hopper over the transfer car extension for storage of materials, or direct to the coal-breaker, to hammer mills, to coal-mixing bin, to oven coal-bin and to oven-filling larrys.

For rail shipment of coal or limestone, a track hopper is provided feeding to the belt conveyor to the coal-breaker, or to the transfer car to storage. For reclaiming coal from storage, the ore bridge feeds the transfer car and is carried to the track hopper and conveyed to the coal breaker.

A battery of 35 of the latest and most modern design of Becker by-products coke-ovens is being installed by the Koppers Company, provision being made for a future capacity of 105 ovens. Double collecting mains will be installed to obviate, as far as possible, the leakage of smoke. The ovens will be designed for complete recovery of by-products. A complete phenol removal plant is being installed, so there will be no stream pollution.

From the gas purification plant a 48-inch main is being placed to carry the air laden with hydrogen sulphid to the direct-fired boilers 500 feet away. This foul air, which is ordinarily thrown out to the atmosphere, will thus be forced through the burners with the blast-furnace gas and consumed under the boilers.

It will be noted that all through the plant considerable thought and expense have been spent in preventing, as far as is humanly possible, the possibility of pollution of stream or atmosphere.

The present blast-furnace stack will be used and will, with very little change, be ready to place in blast in the near future. The four stoves are to be relined with smaller checkers, and consequently larger heating surface, this being made possible by the use of clean gas and pressure burners.

The old dust-catcher is being altered to change outlet connections to discharge into a Bartlett-Hayward 18-foot gas scrubber. The gas will then be used in the stoves and under the gas-fired boilers.

After leaving the scrubber, the wet dust is run through a Bartlett-Hayward thickener, and the thickened dust is carried to a pug-mill under the dry dust-catcher, where the wet dust is pugged with dry dust and charged back into the blast-furnace. This dust-collecting system is closed tight against leakage and will do away with the dust nuisance of the ordinary blast-furnace.

The furnace will cast direct to two 90-ton iron ladles which will be tilted by an overhead ladle crane into a double-strand pig machine furnished by the Pittsburgh Coal Washer Company. These strands pass under a water spray for cooling the pig, and discharge direct to standard railroad cars. Slag will be run direct to a pit, granulated by a stream of water, picked up by an overhead electric crane with a grab-bucket, discharged into an automatic skip hoist to several hopper cars on one track and the iron scrap into a car on an adjacent track. The granulated slag can be delivered direct to bins over the raw grinding department or taken to the ore bridge for storage.

The Allis-Chalmers Company was responsible for the design of the cement plant and the manufacture and installation of the machinery. It will be a wet process plant where the materials are ground, mixed and delivered to the kilns wet. There will be two kilns each of 1500 barrels capacity, with room for a third kiln, giving an ultimate capacity of 4500 to 5000 barrels of cement in 24 hours. Limestone, silicious clays and granulated blast-furnace slag, together with gypsum, will be used in making the cement.

The raw grinding department is located under the present blast-furnace stock-house trestle and bins can be filled with the ore bridge or directly by standard railroad cars.

There will be two slag bins and two stone bins for each of the two raw grinding units. The bins are open bottomed with plate feeders under each, the feeders discharging into weighing conveyors called "poidometers." The ingredients are mixed by weight. The poidometers accurately proportion the mixture of limestone, clay, and the slag which passes over magnetic pulleys, is mixed with a measured amount of water (about 40 per cent.) and passes into the raw grinding mills. For the present plant there are two mills each with a capacity of 75 barrels an hour, but room is provided for four mills. The wet mixture is discharged into a concrete sump on the suction of

Wilfley pumps and discharged into the slurry tanks approximately 500 feet away.

There are eight slurry tanks at present with room for four more. Four of the tanks are for the raw-ground mix just as it comes from the raw grinding mills, while the other four tanks are for correction of the mix. In the slurry tanks the mixture is agitated with Dorr combination horizontal paddles and air agitator. Wilfley pumps are used for transferring the mixture from tank to tank and to filters above the feed end of the kilns, taking the mixture from the bottom of the tank. The mixture is then pumped to continuous eight-disk American filters, one for each kiln, reducing the moisture to about 18 or 20 per cent. before introduction into the kiln for burning. Cloth bags are placed on the filter disks and the water is pulled through the cloth by vacuum. At intervals the bags are inflated and the filter cake broken off and discharged into the pug-mill, where the moist mixture is pugged with dry dust reclaimed from hoppers under the waste-heat boilers and is fed by conveyors into elevators discharging into the pug-mill, and then fed through screw feeders into the kilns. There are two kilns 10 by 175 feet with room in the building for a third.

The cement clinker is discharged through a movable port into the coolers. For each kiln there will be a single cooler 8 by 80 feet. Cold air for cooling the clinker is drawn through the cooler by the kiln draft and directly to the kiln, furnishing 75 per cent. of the air required for combustion. The clinker cascades over a series of paddles to get intimate contact with the cooling air and is discharged into the clinker pit and handled by a Shepard overhead electric crane to the clinker storage. Over and around the exterior of the cooler is placed a heat-reclaiming hood, whence heat is taken to the coal pulverizer for drying the coal.

Each kiln has a separate and distinct unit for fuel preparation. For the pulverized-coal firing this is a No. 5 Raymond pulverizer. Pulverized coal is drawn through a cyclone collector equipped with a motor-driven air-lock valve and discharged into a hopper. At this point a cross conveyor is installed to connect each mill with the feed to either kiln.

Air from the cyclone collector is hot and moist and is drawn into the mill through an exhauster. From the discharge fan, the air to mix with the pulverized coal (25 per cent. for carrying fuel and 75 per

cent. from the cooler) is balanced by dampers through the feeder of the coal injector to the kiln.

Gas fuel will be coke-oven gas direct from ovens before going to the gas-holder. There is a check-valve on the gas pressure, operated through an electrical solenoid control to close on interruption of the power.

The gas control room is separated from the coal-preparation and control rooms by dust-tight gunite partitions, ventilation for this space being provided for by means of a fan exhausting to the outside of the building. The coal-preparation room is also inclosed by gunite partitions.

The gas main outside of the gas control room is provided with a fly-wheel fan, and on interruption of the power the solenoid-operated valve will shut off the gas and the fly-wheel fan will continue to operate long enough to exhaust the explosive mixture from the blast pipe.

There are two separate fuel-feed pipes in each kiln, one for gas and the other for pulverized coal. Over each Raymond pulverizer there will be a coal storage bin of 100 tons capacity. These bins are filled by a 10-ton, Shepard grab-bucket, monorail crane. Over each feeder there will be a 10-ton bin for pulverized coal.

In line with the discharge from the coolers will be a hopper for receiving the clinker and a hopper for the gypsum which is unloaded from cars. These materials are fed through 48-inch Trump two-material feeders through motor-driven feeders into dry mills. These dry "compeb" mills are the same size as the wet "compeb" mills in the raw grinding department.

The finish-grinding mills discharge into the screw conveyors which carry the cement to an elevator to bins over the motor-driven Fuller-Kinyon pumps. Adequate dust-collecting systems will be installed in the finish-grinding department. All motors are in separate dust-tight rooms, and provision has been made for air separation for fine grinding of the cement.

Fuller-Kinyon pumps transport the finished cement approximately 400 feet to the top of the storage bins for the pack house. There are six cylindrical reinforced bins with a total storage capacity of 100,000 barrels of cement. The cement is withdrawn from the bin bottoms and transported by means of two lines of screw conveyors to Fuller-Kinyon pumps, which lift the cement to hoppers over the six

Bates-valve packers, each with a capacity of 150 barrels an hour. The filled bags discharge to chutes to the lower floor for loading on cars, there being two tracks on each side of the pack house. Two conveyor belts, spanning two railroad tracks and a 30-foot driveway, convey the cement to a truck-loading station, with room for a double line of trucks loading underneath. Cross conveyors will be installed so that the bags from any packer can be delivered to any line of trucks without interruption of the flow of cement-filled bags. From the truck-loading station a conveyor belt will connect with a boom conveyor for loading barges in the back channel of the Ohio River.

The conveyor system is so arranged that the output of any or all of the packers can be delivered to cars on either side of the building, to either of the two lines of trucks, or to the river barges, all at the same time or divided as required, without interruption of the flow to any point. Bag cleaners will be provided in the pack house and adequate dust collection will be made throughout the handling system.

There will be a waste-heat boiler installed at the material feed end of each kiln. The gases passing through the boilers will deposit considerable dry dust which will be handled as mentioned above.

After leaving the boilers the gases will be drawn through induced-draft fans with automatic regulation on the fan inlet dampers, which will be controlled by the exit draft of the kiln, and this control can be adjusted by the kiln operator at the firing end of the kiln.

Pyrometers will be installed at the end of the kiln and at the gas outlet on the boilers with the recorder at the firing end of the kiln. When considerable difference of temperature indicates dust deposit on the boiler tubes, signal lamps, located at the recorder, will light and the boiler operator will be notified to operate his soot blowers.

The induced-draft fans are connected into a steel-plate breeching, discharging into a Bartlett-Hayward 20-foot scrubber, equipped with an induced-draft fan to discharge through the scrubber. The gases leaving the scrubber and discharging to atmosphere will be clear and free from cement dust. For the present there will not be a by-pass from the kiln around the boilers into the scrubber, and all of the kiln gases will go through the boilers.

The coke-ovens, blast-furnace and cement-mill are all served from the central power station with steam, water, air and electricity.

There are two boiler houses, both connected to the same boiler feed-pumps and softening system and to the steam header. In the direct-fired boiler house there are four Heine V-type boilers, with 250 pounds pressure, and 8560 square feet of surface, with "Elesco" superheaters for 100 degrees F. One of the four boilers will be fired with a Coxe traveling-grate stoker, with motor-driven forced draft, for burning coke braize and bituminous coal, and fired with Bradshaw pressure burners. Air-injector nozzles are provided through the front ignition arch when using bituminous coal. The remaining three boilers are fired with blast-furnace gas through Bradshaw burners. Two of these boilers are connected through the gas-burners to the purifiers for the coke-oven gas, so that the foul air given off by the purification process will be consumed under the boilers.

An Allen-Sherman-Hoff "Hydrojet" ash-disposal system will be installed under the stoker-fired boiler to discharge into a pit on the outside of the building, where a grab-bucket will load the ashes on cars.

All of these boilers are equipped with "Diamond" soot blowers, and with circular clean-out doors just over the lower drums to provide for soot cleaning by hand where the tubes converge on entering the boiler drum. The two waste-heat boilers are Babcock & Wilcox "Stirling" type, five-drum, with 11,000 square feet of heating surface, equipped with Babcock & Wilcox superheaters.

The four direct-fired boilers and the fuel-burning appliances are designed to operate normally at 200 per cent. of rating, while the waste-heat boiler will probably average about 75 per cent. of rated capacity. All these boilers will operate at 250 pounds steam pressure and 100 degrees superheat. The direct-fired boiler house will accommodate two more boilers, and the piping, breeching, chimney, etc., are all designed for an ultimate capacity of eight boilers—seven operating and one spare. On the direct-fired boilers, the flue-gas passes up through a casing designed to accommodate a future air preheater. When this is added an induced-draft fan will be required. For the present this casing is divided by a steel-plate partition to permit upward flow of the waste gas and downward flow of the fresh air from the Green forced-draft fans, which are driven by DeLaval steam-turbines. This fresh air will be forced into and through the pressure burners or down into an underground duct to the traveling-grate

stoker. Foundations for boiler No. 2 have been installed to permit the placing of a traveling-grate stoker at some future time.

The steel-plate breeching is provided with expansion joints and with connections for future boilers. This breeching discharges into a reinforced concrete chimney, 250 feet above ground level, and 14 feet in inside diameter at the top of the brick lining which is carried for the full height of the shaft.

In general, the piping may seem rather elaborate, but when it is considered that the operation of three complete and separate plants is dependent on the continuous supply of power from a single source, it is best to try to make the power generation as fool-proof as possible.

In designing the piping for all services and in designing the electric cables, allowances have been made for additional boilers, generators, pumps, water-softening plant, etc., for an ultimate capacity to take care of an additional third kiln in the cement plant, two additional batteries of 35 coke-ovens each, and an additional blast-furnace.

The boilers are connected with a single steam-header but looped through the engine-room so that the steam from at least half of the direct-fired boilers or the waste-heat boilers can be delivered from either direction to the turbo-blowers, pumps, generators, skip hoist and to the coke-ovens.

At the boiler feed-pumps, six separate sources of suction are provided so that it is possible to get treated and filtered water, treated but unfiltered water, cold river water, city water, hot well water and high-pressure water from the hot well discharged from the booster pumps. Two separate discharge headers at the boiler feed-pumps and two separate feed lines to each of the two boiler houses should insure continuous water-supply to the boilers. Copes feed-water regulators with excess-pressure regulators will be installed on all six boilers and on the main feed line. Manually operated feed valves will be used on the auxiliary feed line.

River water will be delivered by three DeLaval pumps (each with a capacity of 10,000 gallons per minute, driven by 2200-volt, three-phase, 60-cycle synchronous Westinghouse motors, of 300 horse-power and 900 r.p.m.) to the barometric condensers, and the booster pumps, and by-passed to the coke-ovens.

Three 200-horse-power DeLaval booster pumps, driven by DeLaval turbines at 1800 r.p.m. will be piped with duplicate suction

and discharge headers to enable any one of the three pumps to operate on high-pressure cold water from the main pumps, or high-pressure hot water from the hot well. These pumps, each with a capacity of 5000 gallons per minute, will supply the blast-furnace, water-softening plant, coke-ovens, cement plant, and miscellaneous yard and plant service. Most of the water passing through the barometric condensers will be re-used throughout the plant.

Heat for boiler feed-water will be supplied by exhaust from the four forced-draft fans on the direct-fired boilers, the three boiler feed-pumps, and the three booster pumps, with a direct high-pressure steam connection for make-up.

A Cochrane hot-process water-purification system is being installed with a Cochrane open feed-water heater mounted on top of the softener. This unit will have a capacity of 32,000 gallons an hour, and space and piping are provided for a second unit of the same size.

Two DeLaval blast-furnace blowers will be installed, with room for a third unit when the second blast-furnace is installed. These blowers will operate at 2470 r.p.m. at 30 pounds pressure, with a capacity of 60,000 cubic feet a minute, discharging through an Ingersoll-Rand horizontal check-valve into a 36-inch cold-blast main to the stoves.

Three Chicago Pneumatic Tool Company's air-compressors will be installed in the engine-room. These are driven by Westinghouse synchronous motors on a 2300-volt circuit. The compressors are equipped with intercoolers and aftercoolers. These machines are designed for 110 pounds pressure. Two air receivers will be used with cross-connected piping, so that any machine can be connected to either of the receivers. The 55-pound receiver will ordinarily be used for agitation of cement-mill slurry and one of the 110-pound machines for cement conveying and general plant use. In the event of failure on the 55-pound compressor, any one of the three 110-pound units can be used for the lower pressure service.

Two motor-driven vacuum pumps (Ingersoll-Rand 18 by 10 inches) with 60-horse-power Allis-Chalmers synchronous motors will be located in the engine-room to provide vacuum on the cement plant filters. Space is provided for a third vacuum pump when the third kiln is installed.

Two Westinghouse, 5000-kilowatt turbo-generators are being installed, with room for one more. These are equipped with direct-connected exciters, Worthington oil pumps, governor speed changers, and Andale oil coolers. These turbines will operate at 3600 r.p.m., with 225 pounds steam at the throttle. They are direct connected to revolving-field, alternating-current, 2300-volt, three-phase, 60-cycle generators of 6250 kilovolt-amperes.

Elliott-Ehrhart barometric condensers with Elliott-Ehrhart air ejectors will serve the generator turbines.

The turbo-generators and turbo-blowers will be supported on reinforced concrete foundations, with the turbine floor placed 26 feet above the lower floor.

A system of oil purification for turbine oil will be installed.

Direct current for the coke-ovens, blast-furnace, and for existing equipment in the machine-shop and engine-room will be delivered from two Westinghouse 750-kilowatt motor-generators (2300 to 250 volts), and room is provided for a third motor-generator of the same capacity.

The electric generating equipment consists of two 6250-kilovolt-ampere, turbine-driven generators, with room for one additional 6250-kilovolt-ampere generator. These machines generate 2300-volt, 60-cycle, three-phase current, which is carried directly to the larger motors, and is reduced to 440 volts for the smaller alternating-current motors, to 220 volts for lighting service, and through two motor-generators for 250-volt direct-current service.

The coke-oven battery is served by duplicate feeders for direct current. These are connected to the direct-current bus on the main switchboard and run direct to the ovens. Duplicate 2300-volt feeders for switching gear in the engine-room run to a distribution panel-board located in the present pump-house. This panel-board serves three 2300-volt synchronous motors on the main river pumps. From this panel-board the 2300-volt feeders run direct to the coke-ovens; also to a bank of three 667-kilovolt-ampere transformers (from 2300 to 440 volts) for the coke-oven feeders. The duplicate 2300-volt feeders for coke-ovens and main water pumps are each calculated for the full capacity of the coke-ovens and the pump motors. While in ordinary operation, the water pumps will operate on one of these

feeders and the coke-ovens on the other, either feeder can carry both loads in case one or the other is out of service.

For compressors and vacuum pumps in the engine-room, 2300-volt feeders are led from the breakers. For blast-furnace, ore handling, stock bins, machine-shop, and cranes, direct-current feeders are connected directly to the bus on the main switchboard.

The cement plant is separated electrically, as far as possible, from the remainder of the system. The switch-gear 2300-volt busbars are connected through a totalizing panel with a recording watt-hour meter for the total load of the cement plant. The 2300-volt feeders are connected directly to the switching gear and the 440-volt circuits are served through a short bus over the switch-gear, fed from a bank of four 667-kilovolt-ampere transformers (2300 to 440 volts), connected in open delta. Three of these transformers will carry the load; the fourth will be used as a spare.

The switchboard will be furnished and erected by the Westinghouse Electric and Manufacturing Company. The main switchboard in the engine house will be set on the turbine-floor level, 26 feet above the ground-floor level, with the switching gear located on an intermediate floor 11 feet above the ground floor, with shop and engine-room offices below. The main switchboard will consist of 24 panels with alternating-current instruments at one end and direct-current bracket instruments at the other end. This switchboard will consist of two parts—the alternating-current control board for the 2300-volt and 440-volt circuits, and the direct-current control board for the 250-volt generators and feeders.

Circuit-breakers for the 2300-volt and 440-volt circuits will be type "B" oil breakers, arranged for mounting on a welded angle-iron structure. All oil breakers will be electrically operated from a 60-cell storage battery located on the intermediate floor.

There will be four cement-mill feeder panels and a fifth panel for the cement-mill transformers and cement-mill totalizing meter; a panel for the gas pumps at the gas-holder; one for the coke-oven 2300-volt feeders; one for air-compressors and station auxiliaries; one for the vacuum pumps; one for the 2300-volt lighting panel; a tie panel to the Duquesne Light Company's outdoor switching station; one for battery control; three generator panels; three 2300-volt panels for the motor-generator sets, and three for the direct-current

side of the motor-generators; one panel for coke-oven direct-current feeders and two panels for blast-furnace direct-current feeders. The alternating-current feeder panels are of ⅛-inch steel plates and the direct-current panels of black marine finish slate.

All lighting will be 220 volts, taken from either the 2300-volt alternating-current feeders, the 440-volt feeders, or the 250-volt direct-current feeders.

The switchboard and switching equipment for the coke-oven alternating-current feeders and for the main water pumps will be located in the pump-house at some distance from the main switchboard. This switchboard will consist of 10 panels—three for the main water pumps; one for controlling the primary of the 200-kilovolt-ampere 2300-volt to 440-volt transformer bank; one for the 2300-volt motors of the hammer mill; one for coal and coke handling; one for the battery and quenching station; one for the by-product department; one for the feeder panel for the benzol motors; and one lighting panel, the last five of these items using 440 volts. The circuit-breakers for this board are Westinghouse hand-operated, remote-control units, located in the rear of the switchboard.

Arrangements have been made to tie the electrical generation and distribution systems to the Duquesne Light Company's 22,000-volt line passing the plant. This outdoor switching station will have two 3750-kilovolt-ampere banks of transformers. One bank will be available for instantaneous interchange and the reserve bank for interchange after adjustment of the Duquesne Light Company's load.

All electrical lines connecting the buildings will be lead covered, run in fiber duct, incased in concrete; and inside the buildings all lines will be run in metallic conduit, except the lead-covered cables, which will be run on racks and fireproofed.

Hagan combustion control on the waste-heat boilers will operate from the draft at the kiln end of the boilers to control the kiln draft by regulating dampers on the inlet of the induced-draft fan.

The direct-fired boilers will also be equipped with Hagan control. On the stoker-fired boiler a regulator operating from steam pressure will control the speed of the stoker and the damper of the main air duct for air supply to the stoker.

A combustion control will be used to control the uptake damper in accordance with the draft in the combustion chamber. This con-

troller will be a special machine having a 20-inch stroke instead of the standard 10 inch. The first half of this stroke will control the uptake damper and will swing it from the open to the closed position.

In order to protect against conditions where sufficient quantities of blast-furnace gas are available, together with a low steam pressure which would call for the stoker to be in operation to assist the load and would probably cause a pressure in the furnace due to the fact that large quantities of blast-furnace gas were available, the last 10 inches of the stroke of this controller will operate through a dual control mechanism to take the control of the stoker and the stoker air duct away from the master controller as pressure in the furnace starts to build up. This machine, after having opened the uptake damper wide, will automatically start to slow down the stoker and proportionately cut off the air supply to the stoker.

Forced-draft fans, driven by a steam-turbine, will run at constant speed and will not be controlled except through the damper of the main air duct. On the gas-fired boilers a combustion control will be used to control the uptake damper in accordance with draft in the combustion chamber.

The two waste-heat boilers and each of the four direct-fired boilers will be equipped with a meter for recording steam flow, integrating steam flow, and indicating developed boiler horse-power and percentage of rating. A four-point pyrometer will record uptake temperatures.

The combination stoker and gas-fired boiler will have a nine-point indicating draft-gage—one point for each of the five stoker wind-box connections, one on the gas-burner wind box, one in the stoker furnace, one in the gas furnace, and one in the boiler uptake.

The three gas-fired boilers will be equipped with three-point indicating draft-gages—one point for furnace draft, one for burner wind-box pressure and one for uptake draft.

The waste-heat boilers will each have a two-point recording draft-gage to indicate draft at the end of the kiln and at the boiler exit. On the waste-heat boilers a signaling pyrometer will be used, as mentioned above.

A flow meter will be installed at the water-softening plant, for recording and integrating the water used for boiler feed. There will also be a recording thermometer for boiler feed temperature.

To check gas pressure on the boiler main, there will be a recording pressure-gage.

In the eight-inch steam line to coke-ovens, there will be a recording and integrating steam-flow meter. A combination pressure-gage and thermometer to record total steam pressure and total steam temperature will check steam conditions in the main header at the turbines.

On each of the barometric condensers a recording vacuum gage will be placed, with the recorder located on a gage board in the engine-room office, along with the meters for total steam pressure and temperature, coke-oven steam flow, the boiler uptake pyrometer, an electric clock for checking and setting charts, and the gas pressure recorder. Steam-flow meters will be placed on the steam lines of the turbo-generator and turbo-blower to check steam consumption on these units.

The blast-furnace pyrometers will indicate temperatures on all four stoves, the furnace top and hot-blast temperatures, all on one machine, and recording gages will be provided for furnace blast and furnace top pressures. Two indicating pyrometers graduated from zero to 2000 degrees F. will be used for close readings on top and blast temperatures of the blast-furnace.

The blast-furnace gas scrubbers will have a temperature recorder on the raw gas and on the clean gas; a thermostatic regulator to govern incoming water to outgoing gas; a three-pen thermometer for temperatures of initial water, second stage water and outlet water; a Bailey meter for water flow and a two-pen pressure recorder for raw and clean gas respectively.

The gas scrubber at the cement plant will be equipped with a pressure recorder to show gas pressure on inlet and outlet; also a recording thermometer for incoming and outgoing water.

The reinforced concrete chimney, the concrete bins for the cement plant and the coke-ovens, the foundations and structural steel were designed and built by the Rust Engineering Company, who are also designing the lay-out of the power and steam generating equipment.

Mr. A. P. Meyer, vice-president of the Davison Coke and Iron Company, and Mr. A. W. Kennedy of that company are in direct charge of all design and construction, for the completed units and all of the work is being carried on under their direction.

The plant will shortly be in operation and we are all confident that the finished product will justify our combined efforts.

DISCUSSION

ALBERT P. MEYER:* I do not know that there is much I can say. Mr. Dignan has well described what we are endeavoring to do at Neville Island.

One of the interesting features is the transportation of the cement from the mills by the use of compressed air, under what is known as the Fuller-Kinyon system. The finished product is pumped through a line a distance of over 500 feet and discharged into the silos in this manner. It is then handled from the silos through the Fuller-Kinyon pumps to the packing bins, where the usual Bates-valve packer is used to bag the cement.

There is a condition here in Pittsburgh which is somewhat different from that at other locations, in that the trucking of cement will be the major part of the business; and, in order to meet with the requirements of retaining the cement used by the city of Pittsburgh, or the county of Allegheny, or the state of Pennsylvania, in separate sealed containers, it is necessary to make special arrangements so that this cement can be bagged separately and conveyed for loading to trucks as it is called for. To accomplish this we have gone to extremes in the lay-out of our pack house and truck-loading facilities so as to avoid delay of trucks when they call for cement. We plan, by the use of conveyors, to load a truck every 2½ minutes, and hope to be able to give the service required.

Of course, we have found quite a number of problems in this proposition, as in the first instance we have a coke plant, then again we have a blast-furnace, and again a cement plant, and we are trying to unify the three. They must synchronize, and in so doing, water, steam, air, and electric power must all be given consideration at the same time. Then again, we must be careful to provide for the use of the by-product coke gas in the summer months when the public utility company is not taking it for public use.

We use the waste gas from the blast-furnace under the boilers and the coke breeze to make our steam, as well as the waste heat from the kilns through the waste-heat boilers connected therewith. We are

*Vice-President, Davison Coke and Iron Co., Pittsburgh.

equipped to use powdered coal on the kilns as well as the by-product gas, so that continuous operation is assured.

The center or the hub of our plant is the power-house, and everything radiates from there, but I believe that Mr. Dignan has well explained that point to you.

W. W. Boyd:* May I ask what disposition you make of the dust from the furnace?

G. E. Dignan: The old dust-catcher is to be changed somewhat; the furnace connection instead of going into the top will connect into the side and go out of the top into the scrubber.

The dry flue-dust from the dust-catcher will be mixed with wet flue-dust from the thickener, taken to stock bins, mixed with ore and recharged to the blast-furnace.

Albert P. Meyer: I think the point in which the gentleman is interested is the handling of the dry flue-dust from the blast-furnace. We plan to use the slurry from the Genter thickener and pug the wet and dry dust together from the dust-catcher into a railroad car. This car will then be taken around to the stock pile, and the wet and dry dust filled back into the furnace.

J. S. Green:† Mr. Chairman, I would like to ask a question about the waste-heat boiler. Did I understand that it is a header type? I have a couple of waste boilers under my supervision, now, and on the horizontal type we have quite a lot of trouble with sediment and dust. It is hard to get it off.

G. E. Dignan: No, the waste-heat boilers are Babcock & Wilcox "Stirling" five-drum boilers. These are equipped with soot blowers and in addition will have soot doors over the lower drums so that soot accumulating where the tubes converge at the drum, can be removed with a steam lance.

W. W. Boyd: How is the coke to be quenched after it comes from the ovens?

G. E. Dignan: The present plans are for wet quenching in the ordinary manner.

*Chief Engineer, Standard Scale & Supply Co., Beaver Falls, Pa.
†Master Mechanic, Edgewater Steel Co., Oakmont, Pa.

COST-SHEETS AND THEIR RELATION TO ENGINEERING ECONOMICS*

By W. B. Skinkle†

Comparison of cost-sheet data with the engineering economics of given industrial situations is a subject capable of almost infinite expansion and elaboration. The proper solution of industrial problems often presents a multiplicity of perplexing problems which at times become so confusing and involved in their relations and interrelations that they almost defy solution, and in many such cases the engineer must, of necessity, fall back on plain ordinary horse-sense as a basis for his decision. Much of this confusion can be eliminated by the application of the proper methods of solution and by attacking the problem from the proper viewpoint.

In solving a problem, many engineers use only analytical methods and when a solution is reached, this solution holds for only the one point of production which was used as a base; whereas, if the same solution were applied at some other point of production, the decision might be completely reversed.

It is well known that the load, or the production, of a given piece of equipment has a great influence on the unit costs. In enlarging on this idea, the author presented a discussion of power costs before the Association of Iron and Steel Electrical Engineers in June, 1928,‡ in which he offered proof from both a purely mathematical and a practical standpoint that costs could be divided into two parts—a "constant" cost which is independent of the production; and an "increment" cost which, within certain limits, is directly proportional to the production.

In order to clarify arguments and illustrations that will form the basis of this paper, it is believed that a short repetition of data previously presented will be of advantage. The various illustrations used will all be based on power because power costs offer an ideal subject for such analyses as will be undertaken. The output or product of a turbo-generator is always the same in kind. A kilowatt-hour is just the same in January as it is in July. For a given generator, it

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†Engineer, Pittsburgh District Power Committee, Subsidiary Companies of U. S. Steel Corporation, Pittsburgh.

‡*Iron and Steel Engineer*, v. 5, p. 278.

is made from the same machine, the same raw materials and the same labor. The variables entering into the cost of power can, therefore, be reduced to that of "time" and "output."

Most men think of cost in terms of "a unit of product"; speaking electrically, they think of, and try to compare, the cost per kilowatt-hour. Take, for example, any comparatively large turbo-generator, and plot the cost per kilowatt-hour against load-factor; or, preferably, the kilowatt-hours produced in a unit of time, and we get the old familiar curve like Fig. 1, where the cost per unit of product is con-

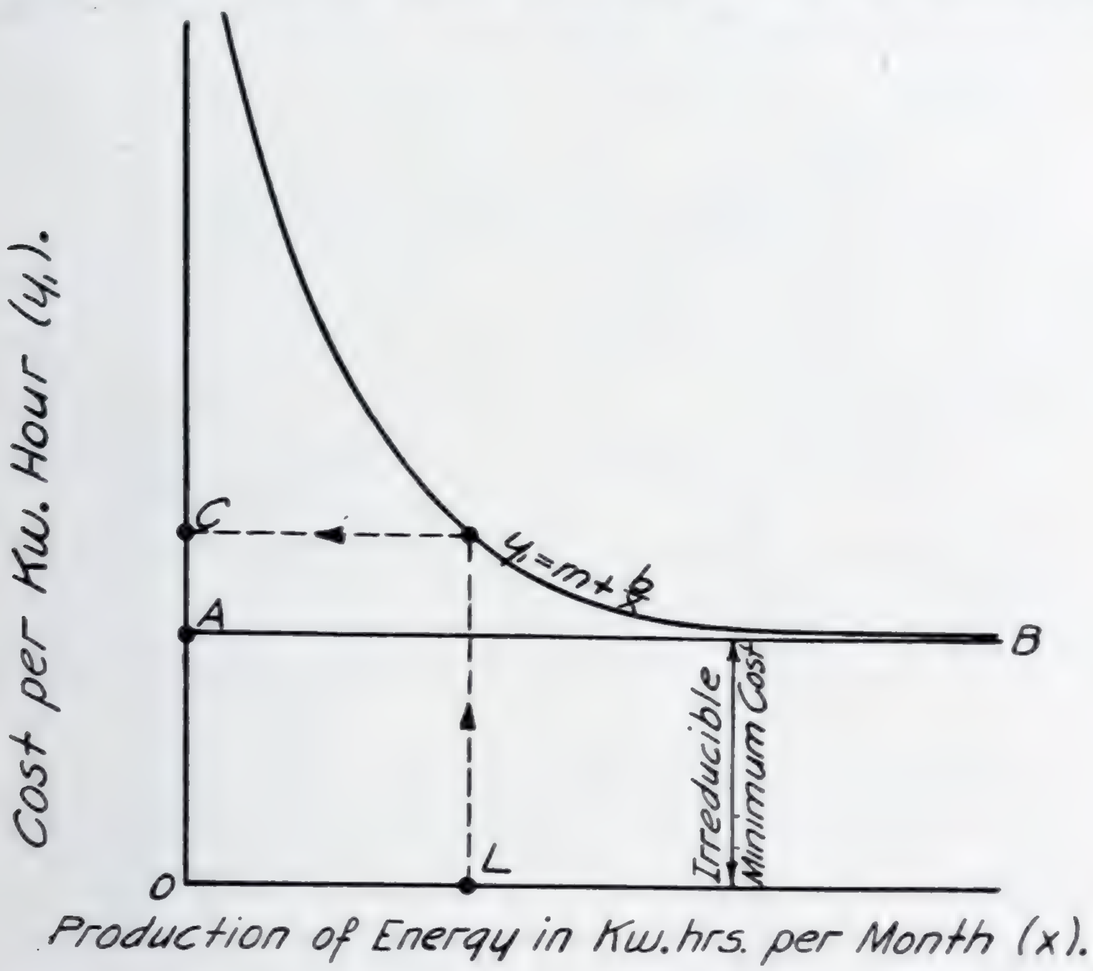

Fig. 1. Typical Curve of Unit Cost Plotted against Production.

tinually lessening as the number of kilowatt-hours produced increases, the lowering costs per kilowatt-hour approaching an irreducible minimum, that it never quite succeeds in reaching. This irreducible minimum cost is represented by the line AB and may represent the cost of fuel, some labor, fixed charges, etc.

Thinking of this curve from a purely mathematical standpoint, we are at once struck with its similarity to the definition of a hyperbola, which is a curved line that continually approaches a straight line called the asymptote, but which it never reaches at any distance

short of infinity. Such a curve has the general algebraic form of $y_1 = m + \frac{b}{x}$.

If the total cost of operating a power-house which was producing OL (kilowatt-hours) were wanted, it would be obtained by multiplying the kilowatt-hours produced (OL) by the cost per kilowatt-hour (OC), and the result should equal the total money spent for power as shown on the cost-sheet. Let us do the same thing with the general equation of our hyperbolic curve; in other words, get a new total cost, y, by multiplying y_1 by x, or expressed algebraically

$$y = y_1 x \qquad (1)$$

In the general equation, we find that $y_1 = m + \frac{b}{x}$.

Substituting this in equation (1), we have $y = x\left(m + \frac{b}{x}\right)$, which when simplified gives us

$$y = mx + b \qquad (2)$$

This equation is the well known straight line. It will take the form of Fig. 2, in which

x = the production of energy in kilowatt-hours per month (OL).

y = total cost of energy in dollars per month (OD).

b = a constant cost which is independent of the production.

m (which is the slope of the line) = an "increment" cost per unit of product, which is directly proportional to the quantity of energy produced.

In other words, a production of energy x equal to the horizontal distance OL would give a cost y equal to the vertical distance OD, which cost would be made up of the sum of a constant cost b plus an increment cost mx.

A purely analytical solution comparing two pieces of equipment producing the same quantity of material would fail to bring out these constant and increment costs; but, when a graphical solution is presented, the whole situation is often cleared at once.

Fig. 3 illustrates this point. Here two pieces of equipment, A and B, having different "constant" and "increment" costs are shown,

with the cost as the vertical ordinate and units of production as the horizontal ordinate. Unit A has a constant cost equal to the vertical height OA and an increment cost shown by the slope of the full line. Unit B has a constant cost equal to the vertical height OB and an increment cost equal to the slope of the dotted line.

The cost of producing any number of units of product is shown by the vertical distance from the base-line to the intersecting point on

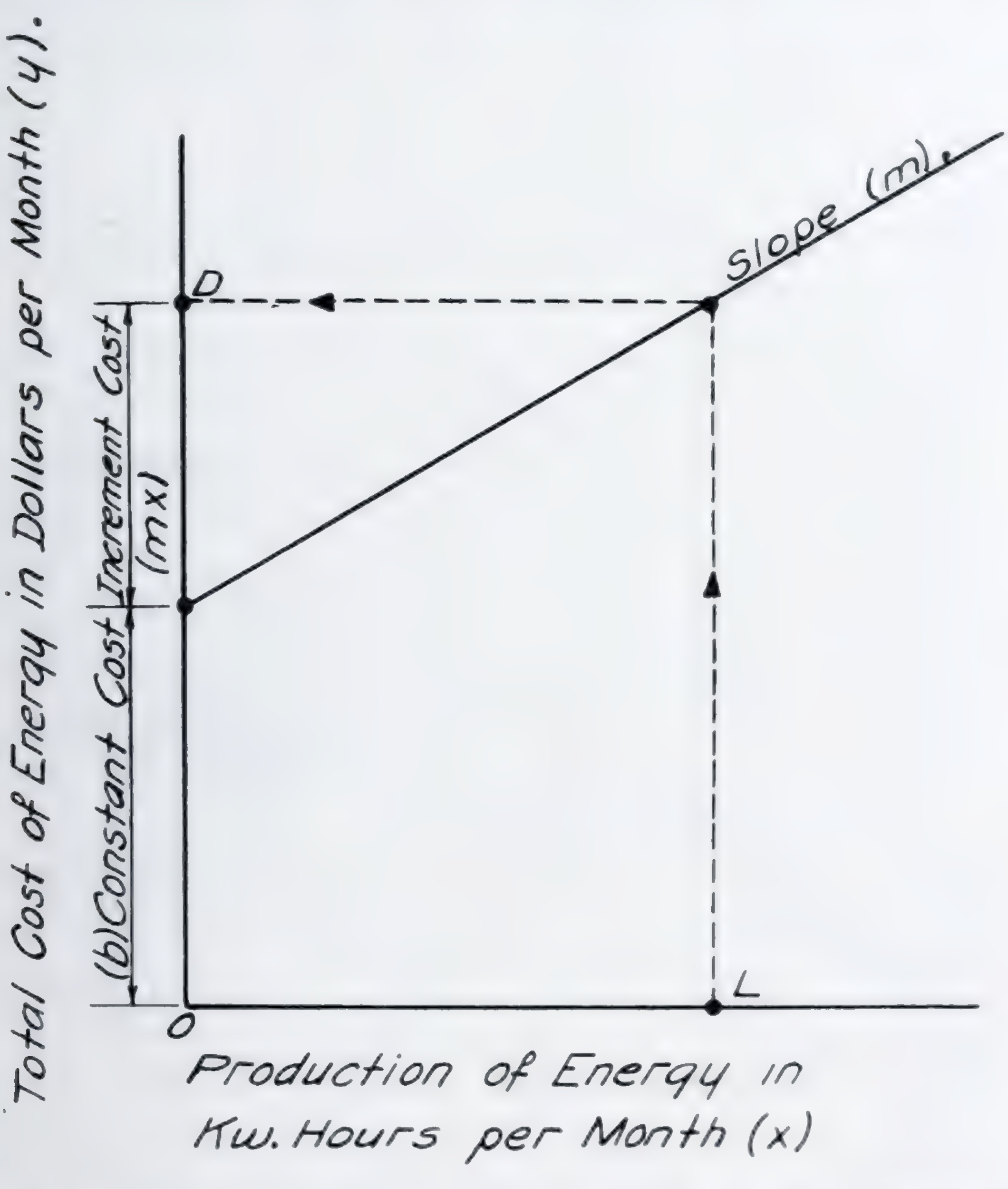

Fig. 2. Typical Curve of Total Cost Plotted against Production.

the sloping line for either unit. For example, the cost of producing a quantity of material equivalent to the distance OL on unit B would be shown at C, while the cost of producing the quantity of material equivalent to OL_1 on unit A would be shown at C_1. If an analytical solution is offered, using the production OL as a base, it is apparent that unit A would be chosen; but, if the production OL_1 is used as

the production base, the decision would be reversed and unit B would be selected.

Graphic solutions of this type are also very valuable for use in showing tendencies. Suppose, for example, the "present production," or the production as shown by past records, were such that the output was at, or near, the crossing point X of the two cost lines. The probable future production would then have a very important bearing on which piece of equipment was chosen. If indications pointed

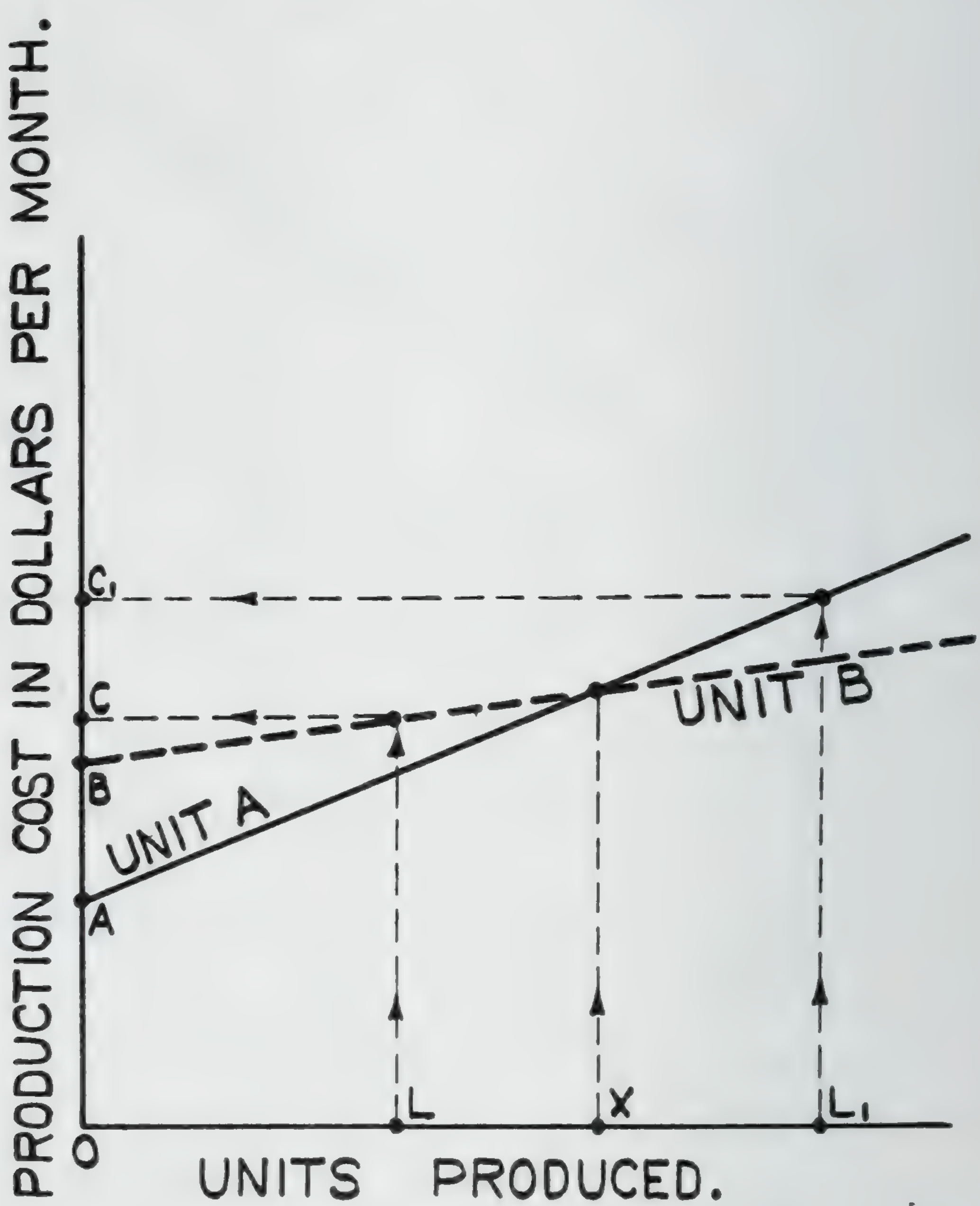

Fig. 3. Graphic Comparison of Total Costs of Two Pieces of Equipment Producing the Same Article.

to larger output in the future, unit B would be the choice; whereas, if indications pointed to a decreasing future market, unit A would certainly be installed.

Solutions of this kind would be comparatively easy if cost-sheets contained records that could be plotted, and curves of this type could be drawn. Unfortunately this is very seldom the case. When it is tried, the results are often close to ridiculous and the cost records must often be subjected to the most minute scrutiny and analysis before any reason for the changes in cost, for changes in load, can be discovered; yet many engineers are continually referring to the cost-sheets for information and often accepting that information as basic and final with little or no attempt on their part to analyze the data and correlate the facts in proper relation to each other, or to the whole.

Industrial cost-sheets are simply records of past expenditures, carefully segregated and classified, so that they can be charged to the proper items or accounts. They *do not* attempt to set forth the "economics" of an industrial situation, and while they do attempt to take careful account of the difference between capital expenditures, maintenance, operating and production costs, etc., there are always a large number of expenditures in what might be termed the twilight zone, which are very difficult to classify. Furthermore, industrial equipment has an unfortunate habit of requiring major expenditures at more or less widely separated and irregular intervals of time when complete overhauling or rehabilitation is necessary.

Monthly and even annual records of past expenditures are very likely to be exceedingly erratic, particularly so if they are taken in relation to the production of the unit. A good example of this is seen in the records of operating costs of a turbo-generator station when these operating costs are plotted against the production.

After correcting the fuel cost to a common base, for uniformity, the cost-sheet gave the results shown in Fig. 4 for 33 successive months of operation. In this figure, the operating cost in dollars per month is used as the vertical ordinate and the production in kilowatt-hours per month is used as the horizontal ordinate. The star shows the weighted average cost and production for the period covered.

To say that results shown by the cost-sheet are somewhat erratic seems to be stating the case rather mildly, yet the cost-accounting system used by this company is a most complete, carefully laid out and maintained system. Here is a case where the identical piece of equipment is producing an identical product month after month, with

the same raw materials used for production and the same force of workmen who were paid the same wages throughout the period, and yet the erratic variations in costs appear to be almost ridiculous. The results after the items had been analyzed and separated into their

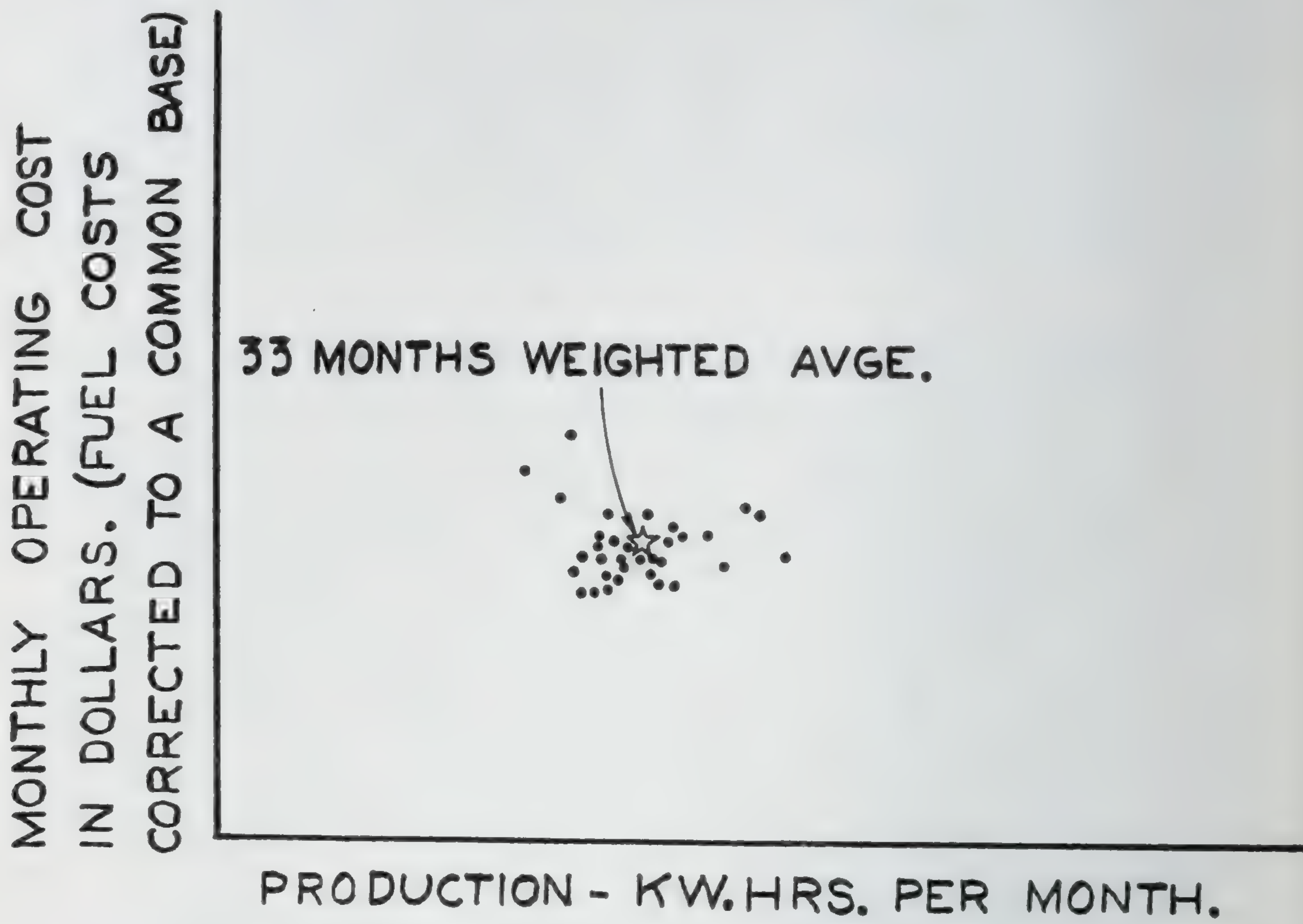

Fig. 4. Costs of Turbo-Generator Station When Plotted against Production.

constant and increment portions, are shown in Fig. 5. In this figure, the original position of the monthly costs has been preserved and they are still as erratic as ever, but it will be noticed that the weighted average cost for the average production coincides almost exactly with the theoretical total cost line.

The analysis developed the fact that, aside from the varying cost of fuel which was corrected to a uniform average cost before any points were plotted, the most erratic item in this particular case was the cost of repairs. The three months of high cost and low production (on the left, marked A), are months of major repairs. During two of these months the turbine was rebladed. All of the cost of material and labor was charged into the months when the expense was incurred and in which the machine was shut down for a consid-

erable period. The production cost was, therefore, disproportionately high.

During the three months included in B, this turbine was operated at high rating for long periods in order to replace the output of other machines which were shut down for overhauling. It seems that the costs for both groups are very misleading. There is no more cause for pride in a record month of low costs, such as are represented by

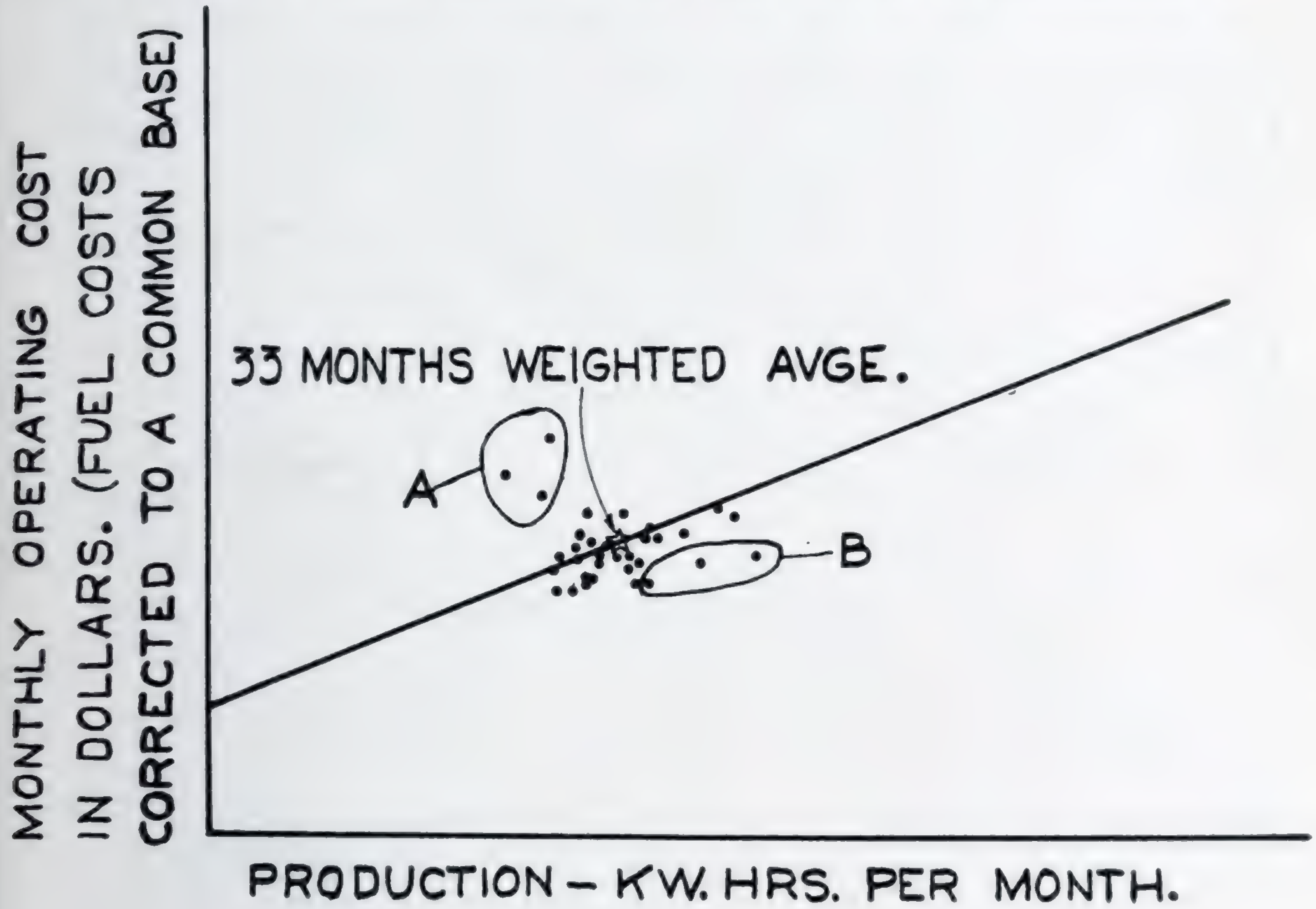

Fig. 5. Costs of Turbo-Generator Station When Plotted against Production, with Theoretical Cost Line Added.

the points of group B, than there is for worry on the high costs as represented by group A.

Repairs and replacements constitute an unavoidable item of expense, and why should one month or one year be loaded with expenses that have been gradually accumulating over a period of one, two or three years? Manufacturing enterprises carry fire insurance, paid at regular intervals in order to avoid the financial shock of loading a more or less remotely possible major expense onto a plant or department for a major item of expense which *may* happen. Why then should they not carry a similar fund into which is paid a regular

amount to cover a heavy expense item that is absolutely *sure* to happen?

In order to illustrate how erratic costs such as we have seen in Fig. 4 and 5 can be analyzed and brought into a reasonable relation to the load and to each other, an analysis of the cost of operating a boiler house for 24 consecutive months is shown in Fig. 6. As is indicated

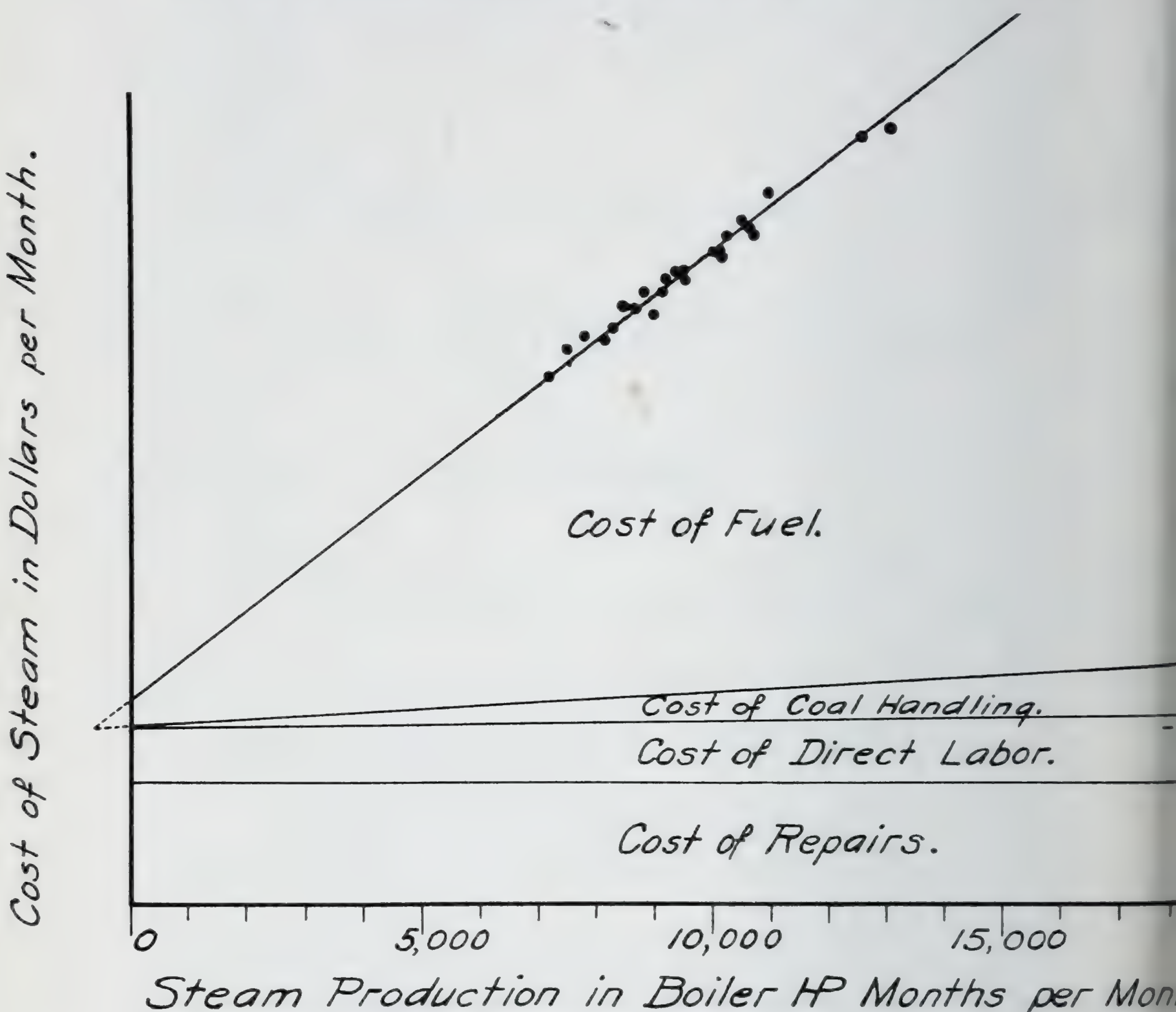

Fig. 6. Cost of Operating Boiler House.

in the diagram, the costs of steam were divided into general headings of repairs, direct labor, coal handling, and fuel. Each item in each division was carefully analyzed and plotted over the two-year period in order to determine the percentage split between the con-

stant and increment cost. The total costs for each of the various subdivisions were then assembled and the constant and variable costs of the whole boiler house determined.

Major repairs which occurred at comparatively long and widely separated intervals of time were funded so that each month carried its proper share of these major items and the total was not loaded onto any particular month. The monthly fuel costs were then corrected to the weighted average price of fuel and the whole put together in the diagram of Fig. 6. Note that the range of monthly load over the 24 months varied from 7000 to 13,000 boiler horse-power months, which is a variation in load of 85 per cent., while the maximum cost variation over this range of load was two per cent. (plus or minus) from the theoretical cost line.

Costs kept on this basis would be an invaluable aid to the engineer instead of the delusion and snare which they often prove to be when taken in their present state, without the clarification of careful analysis.

Let us return to the previous graphs of cost-sheet figures, and examine Fig. 7 which illustrates these variations.

Note that the range of production is from approximately 2,400,000 to 4,400,000 kilowatt-hours—a variation of 84 per cent.; also note that the variation from the lowest to the highest cost is just about as great as the variation in production. This machine operated at almost exactly the same total *cost* for the month indicated by points 1 and 2 and yet the *production* at point 2 was 65 per cent. greater than the production at point 1. Similarly, it can be seen that the months shown by points 3 and 4 were months of equal *production*, yet the *cost* of month 4 was 63 per cent. greater than the cost of month 3. Continuing further, compare the *unit* cost, or in this particular case, the cost per kilowatt-hour as indicated by point 2 with that of point 5. The 85 per cent. greater production of point 2 cost 30 per cent. less money. This represents a variation in monthly unit costs of very nearly 240 per cent., and yet these cost-sheets show costs for the same machine producing the same product with the same raw materials and with costs reduced to the same base. The machine is also operated by the same laborers who are paid exactly the same wages. All variables have been removed except those of time and production.

In view of such possible wide variations, can cost-sheet data be used by an engineer for accurate comparisons without a very liberal dose of the "salt" of careful analysis?

One of the most confusing and misleading phases of costs is the constant tendency of engineers to mix cost-sheet "book values" or cost-sheet "credits" with the actual engineering economics of an industrial

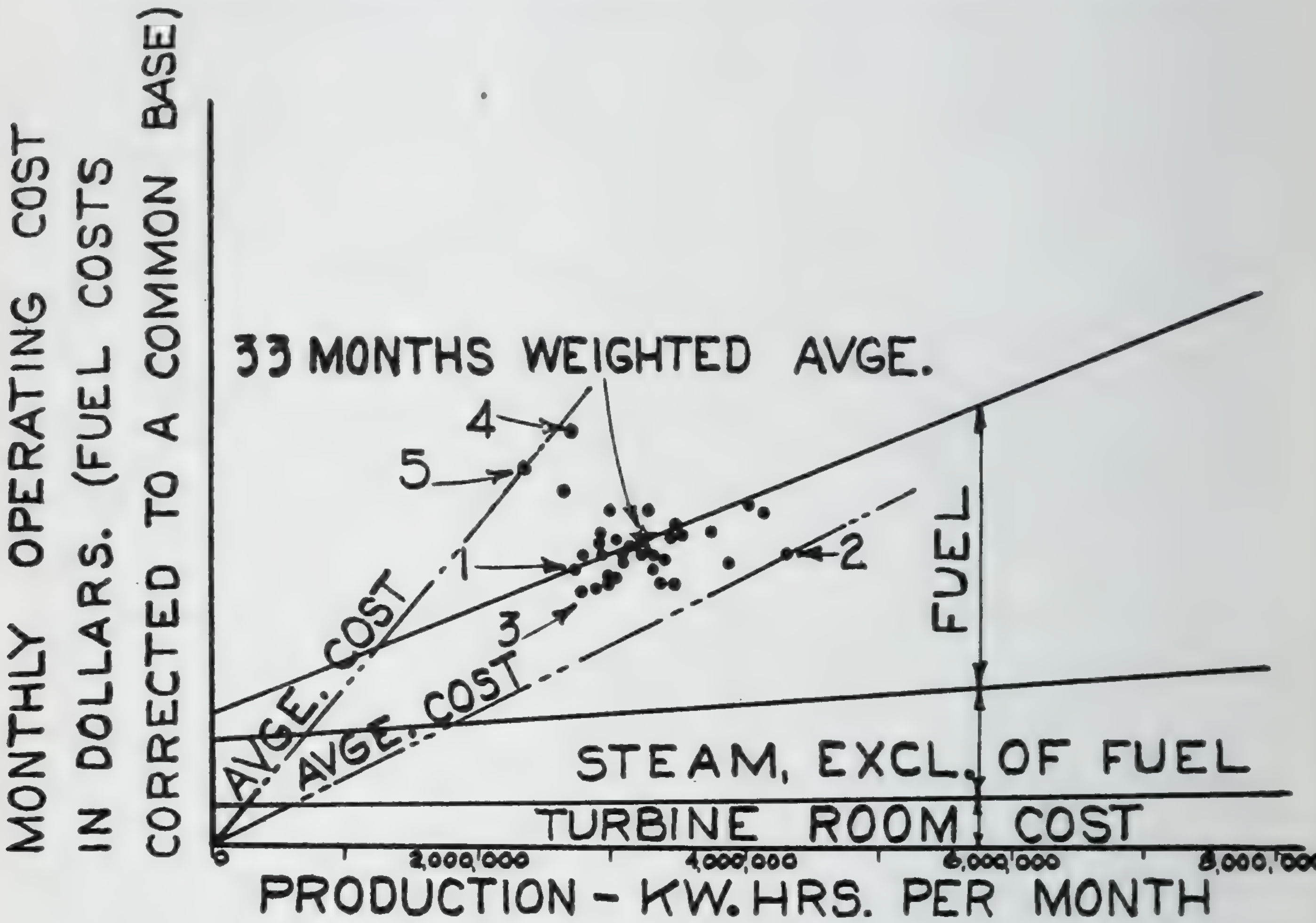

Fig. 7. Variations in Power-Plant Cost-Sheets.

situation. This is particularly true when attempts are made to figure the savings resulting from changes in equipment.

The very strong tendency of many engineers to be governed entirely by the apparent showing of book values as reflected on the cost-sheets, and their efforts to maintain or increase a favorable showing of these "book costs" often hinder or prevent entirely the starting of programs which would ultimately lead to big returns.

Monetary savings are one of the most perplexing and misleading things which an engineer is called upon to calculate; particularly so if the cost-sheet book values are used as a basis for the calculations. To illustrate this point, a case is recalled in which a motor replaced a worn-out steam-engine. The management wished to know what sav-

ing had resulted from the change. Reference to the cost-sheet showed that, among many items, the cost of steam for this engine was $60,000 a year; and, further, that the cost of the purchased electric energy which replaced the steam was $20,000 a year. Any schoolboy could see, without half trying, that the saving on the item of steam cost was,

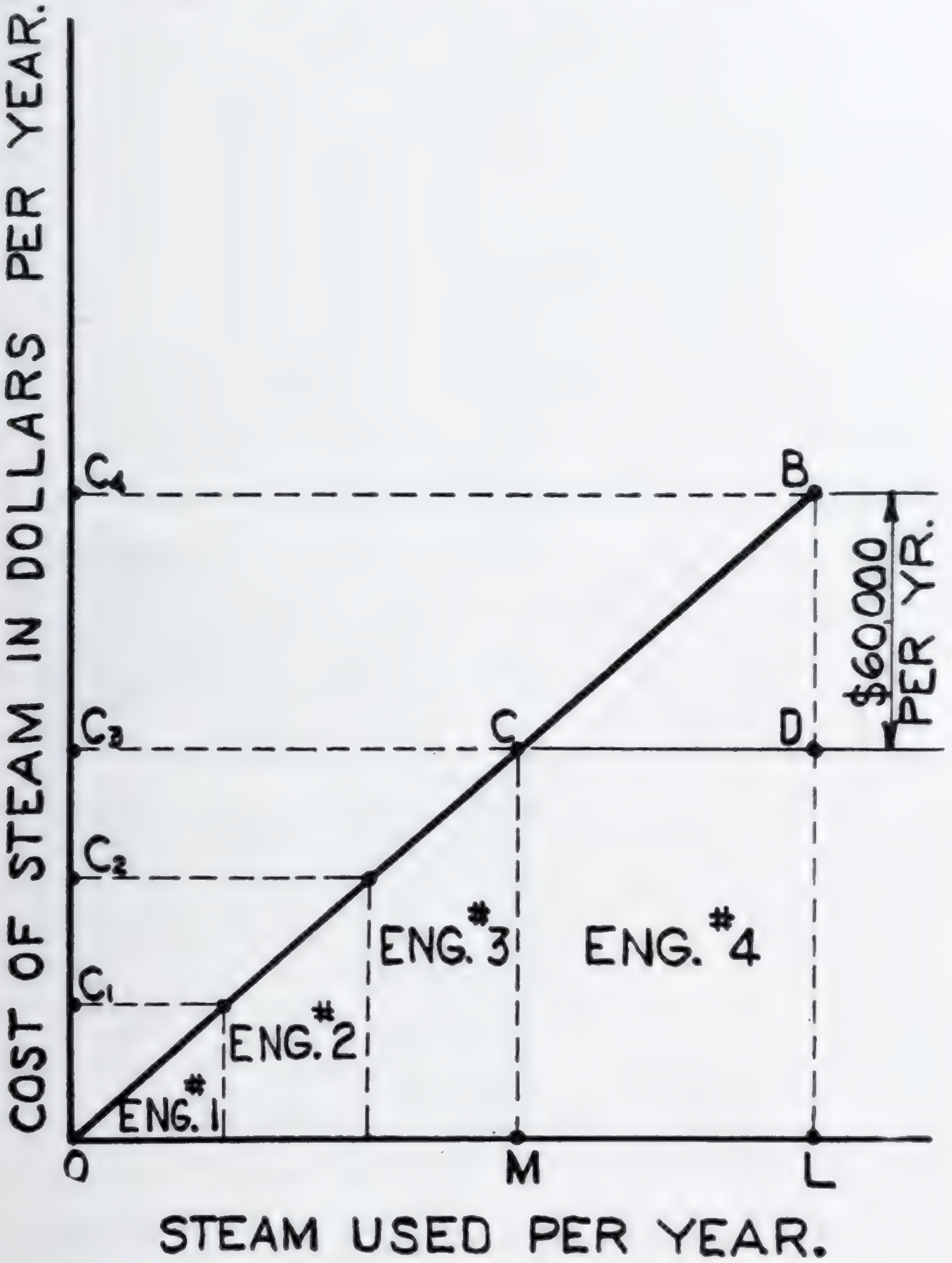

Fig. 8. Graphic Representation of Typical Cost-Sheet Distribution for Steam.

therefore, $40,000 a year, inasmuch as a $60,000 item had been replaced by a $20,000 item on the books. The steam cost distribution as reflected in the cost-sheets is shown diagrammatically in Fig. 8. In this figure, the plant steam distribution has been simplified to four steam-engines for the purpose of illustration.

The annual cost of steam in dollars is plotted as the vertical ordinate while the steam production is plotted as the horizontal ordinate. The total production OL was shown on the cost-sheets to have cost OC_4 dollars and this cost was charged to the four engines in the ratio of their tested steam consumptions. Engine No. 4 used a quantity of steam represented by ML, which was charged on the cost-sheets as the vertical distance from C_3 to C_4.

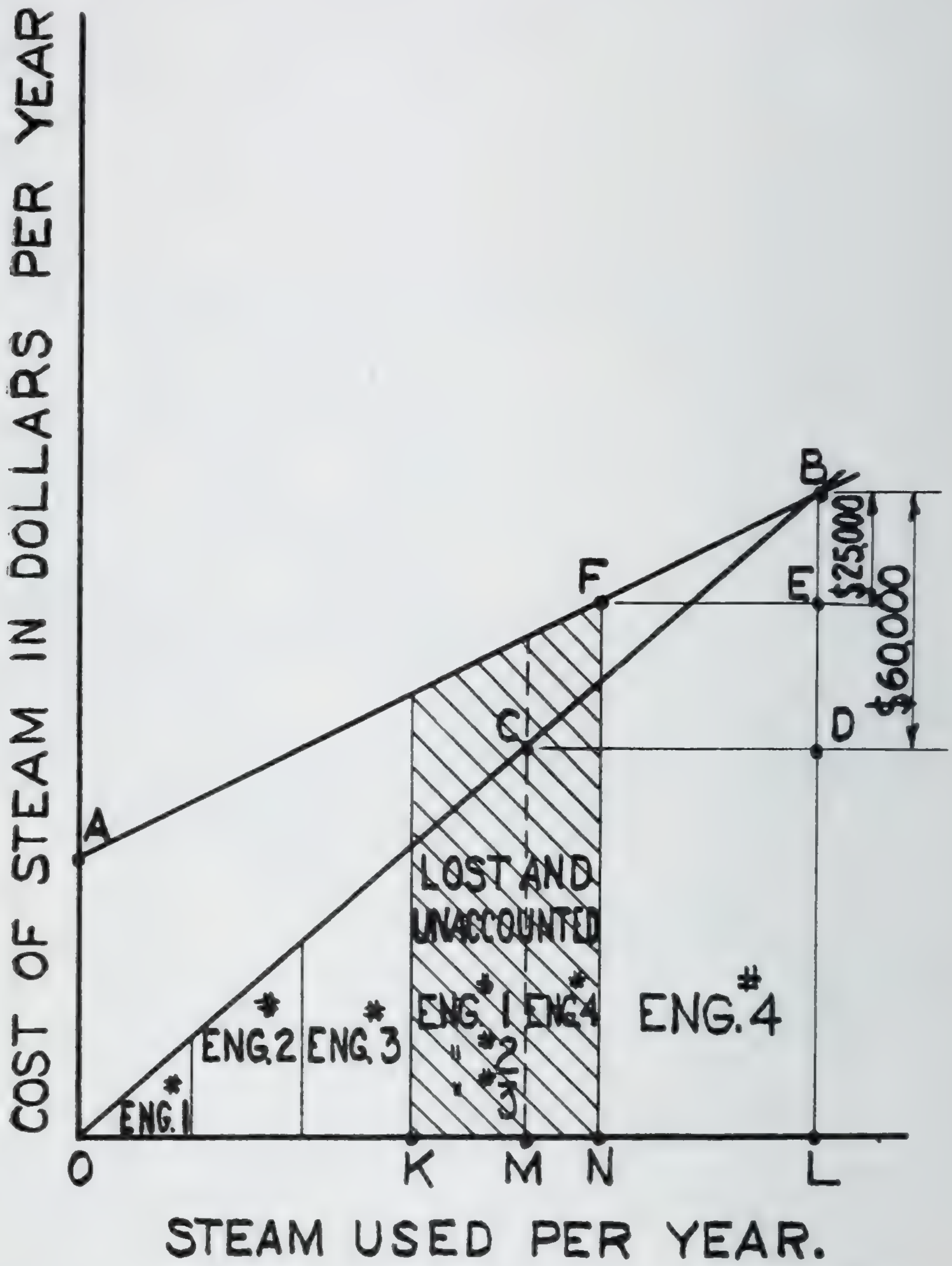

Fig. 9. Graphic Representation of Economic Analysis of Steam Costs Shown in Fig. 8.

Let us refer to Fig. 9 and see what really happened to the costs. A careful analysis of the steam cost at this plant showed that it could be analyzed into its constant and increment costs, the constant cost

being equal to the vertical height OA, and the increment cost being equal to the slope of the line AB. Engine No. 4 was replaced by the motor. The actual steam used by each engine, as determined from tests, is plotted along the horizontal axis, and, in addition, a large amount of lost and unaccounted for steam is represented in the shaded area in order to make the steam consumption balance with the steam production. Each of the several engines was charged on the books with its proportionate share of the lost steam, so that while engine No. 4 actually used an amount equal to NL, it was charged on the books with an amount equal to ML. The "book value" of this steam is the average cost, and the amount charged to engine No. 4 is shown by the vertical height DB. Furthermore, when the engine was replaced by a motor, only one short branch steam line was removed, and this removal had almost a negligible effect on the quantity of lost steam. It follows, therefore, that when engine No. 4 was removed, the load on the boiler house was lowered only by an amount equal to NL and the change in cost instead of moving down the "average" line from B to C, as shown by the cost-sheets, actually moved down the "increment" line from B to F, and the actual reduction in costs is shown by the vertical height EB, which was found to be $25,000 a year instead of $60,000 a year as shown on the cost-sheets. If this reduction of $25,000 in cost of steam was replaced by a $20,000 cost for purchased power, the actual saving in this item was $5,000 a year instead of $40,000 a year, which is only one-eighth of that shown by the cost-sheets.

If the foregoing calculations on the cost of the electric energy were made from the records of a watt-hour meter, the same error of assuming average costs is again entering the analysis.

On January 29, 1929, the author presented a paper before this Society, entitled "Purchasing Public Utility Power for Industrial Use,"* in which several public utility schedules were analyzed and discussed. It was shown that the schedules for purchasing power could be graphed in the manner shown in Fig. 10. Suppose that the plant was consuming a quantity of energy represented by OL with a demand A, and the watt-hour meter showed that this particular motor added to the power consumption an amount equal to LL_1, making a new total energy consumption OL_1. If the new motor increased the

*PROCEEDINGS, v. 45, p. 57.

demand on the plant to B, then the line of average costs (OB) used for cost-sheet distribution did not change and the analysis was correct. Suppose, however, that the new motor was operated at a poor load-

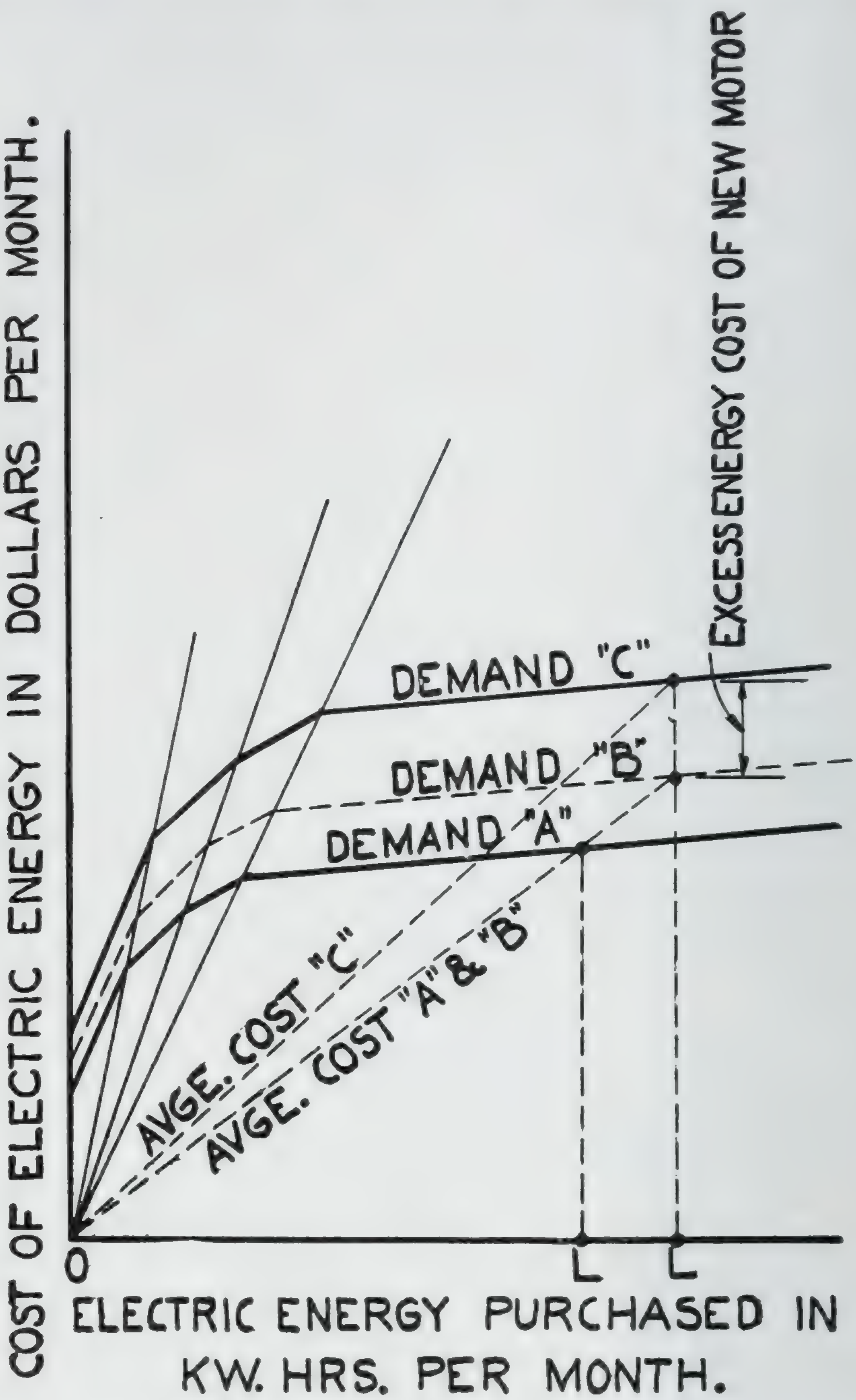

Fig. 10. Graphic Representation of Cost of Purchased Electric Energy.

factor and the demand instead of increasing only to B actually increased to C. Under these last conditions, the cost of electric power for this motor would have an excessive increase indicated by the vertical

height BC, and the $5000 saving could easily dwindle into an actual loss. This loss would not be shown on the cost-sheets because the excess cost would be distributed over all the motors in the works and the new motor would assume only a small part of the extra cost burden it had imposed on the power bill.

This offers an interesting case. A study of Fig. 9 would seem to indicate that when taken on its own merits, it might be said that the substitution of the motor for the engine did not pay, or at least the return would be small. The same could be said of motorizing engines No. 3 and No. 2 in succession; but when the last engine was motorized and the boiler house shut down, the change would prove to be almost a "gold mine."

Each step should be part of a general program of electrification and the whole series must often be kept in mind before a real justification can be found for the first step.

Another interesting study deals with the relative merits of the various types of economies made. In analyses such as these, there might be two general types:

1. Economies affecting the increment costs. These could be along the lines of efficiency.

2. Economies that affect the constant cost. These would be along the lines of fixed charges on the investment, or they might affect any other item of the constant cost.

A glance at Fig. 11 will show that the amount of savings in the increment cost is entirely dependent on the production of the unit, while any saving in the "constant" portion of the costs is just what the term implies—that is, constant throughout all ranges of production.

Dividing the cost into these two parts segregates the items into their proper relation to each other and indicates where to place the effort on cost reduction. On units of high-load factor, large returns can be made by fairly small increases in efficiency, but large returns for a given effort may be secured by reductions in the "constant" portions of the cost.

In conclusion, it is deemed advisable to repeat some of the thoughts which the author has tried to emphasize; they are about as follows:

1. Industrial cost-sheets are simply records of past expenditures and, no matter how carefully they are kept or how minutely they are

subdivided, they should not be used as a basis for calculations of changes in either equipment or operating conditions unless and until they are carefully analyzed and arranged in their proper relation to each other.

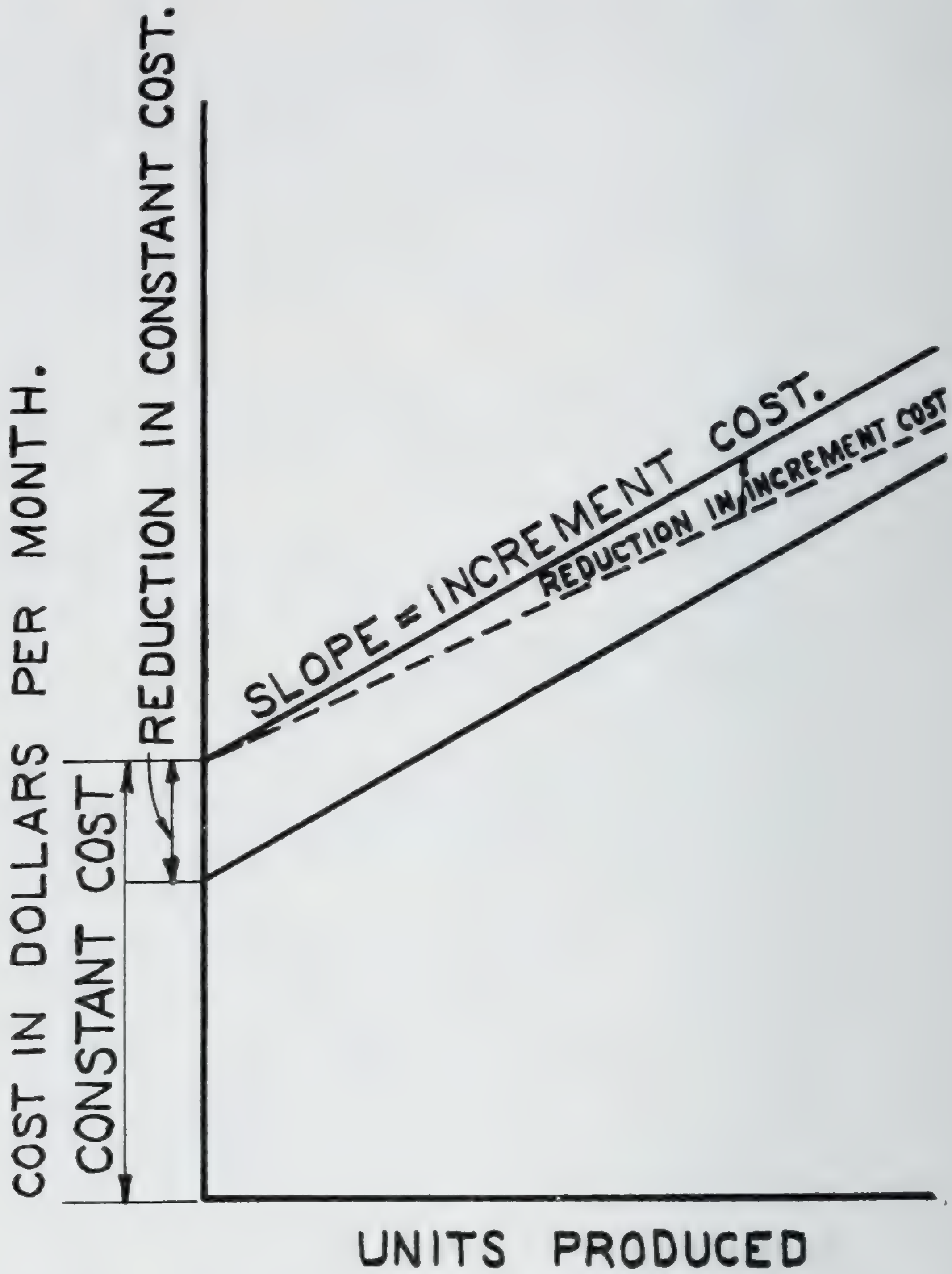

Fig. 11. Comparison of Increment Cost and Constant Cost.

2. Graphical diagrams similar to those presented in this paper will often clear a puzzling situation and explain many apparently contrary conclusions.

3. In making comparisons between two sets of operating conditions, be sure that the comparison is based on the actual money in-

volved, and not on a mystifying set of book values of by-products and transfers of credits as between departments.

4. When figuring savings that have resulted from changes in equipment, do not "kid" yourself or your superiors by using a lot of average costs when in actual reality the changes in cost are moving along an increment line which is very much flatter than the average cost line.

DISCUSSION

B. R. SHOVER, *Chairman:** Mr. Skinkle has presented in a very clear and comprehensive manner his method of using increment costs. Quite frequently the results attained by an improvement or addition to a plant fail to verify the engineer's prophecy, because the effect of increment cost has not been taken into consideration.

If all items in the present cost of any operation are put in one column and the expected cost of each item after the improvement has been completed be collected in a second column, the sum of the two columns will represent Mr. Skinkle's method of increment cost as applied to one particular assumption. The advantage of his manner of calculating the costs means that, once done, the expected results for almost any condition, load, etc., can be arrived at from the curves without special calculation, and also the tendency of cost is clearly shown.

W. H. DUPKA:† Speaking from an auditor's standpoint I believe Mr. Skinkle's views with respect to provisional accounts for repairs are very largely met to-day in many steel-plant accounting systems. Most companies now have provisions for renewal of rolls, molds, and stools; provisional funds for relining of blast-furnaces, rebuilding open-hearth furnaces, and by-product coke-ovens; and provision for repairs of heating furnaces and pit furnaces, etc. These provisions cover a large proportion of the charges for repairs and maintenance.

Regarding the suggestion for the funding of repairs to buildings and machinery, this is now being handled by some companies in a rather limited way, in that repair jobs estimated to cost in excess of

*Consulting Engineer, Pittsburgh.
†Controller, Jones & Laughlin Steel Corporation, Pittsburgh.

a certain sum are funded. This in the individual case will depend upon the number of departments and the units in each department. A large steel company would have many hundreds of departments and in most cases several units in a department, thus making thousands of items that, on Mr. Skinkle's basis, would have to be funded. It might prove impracticable to handle all accounts in this manner, as the cost of maintaining such reports would be more than they would be worth or any possible saving could justify; that is one thing that, of course, would have to be kept in mind. If such repairs were funded over more than a year (which in many cases would be necessary because certain of the larger units would not be overhauled within such period) it would conflict with the federal income tax regulations which do not permit as taxable deductions, accruals for repairs. Of course, some companies charge certain repairs to costs, regardless of the period of duration over which the repairs are made, and other companies charge major repairs to depreciation. This objection can be somewhat overcome by charging to depreciation reserve the major repairs accruing over a long period of time.

Another point concerning Mr. Skinkle's suggestion is that the proposed method obscures the effect of the cost of repairs in that it spreads such costs over a long period rather than allocating the costs to the month in which they are made.

W. B. Skinkle: On the subject of funding repairs Mr. Dupka has brought out a number of valuable points which are worthy of careful consideration and analysis, and while I have known of the "blast-furnace relining fund" and the "open-hearth repair fund," I did not know that the funding idea had spread beyond these two departments. Let us hope that, as more thought is given to the subject, the extension of the idea may be put to further applications than are in effect at the present time.

Discussing Mr. Dupka's remarks more in detail, I would say that it was never the author's intention that each individual machine or unit should have its own individual repair funds. It is, however, possible to divide the producing departments of a plant into general groups and fund the repairs for the general group without too much added overhead expense, or, as we sometimes say, without the addition of too many "tons of paper per ton of steel."

Mr. Dupka says that funding accounts could probably not be held open for more than a year, one reason being a direct violation of the income tax rules. In reply to this, I would point out that blast-furnace linings last much longer than a year and I do not believe that the costs for the particular year when the relining takes place should be "punished" by having to absorb the entire expense of the relining. Further than that, the United States income tax rules are comparatively new and have not stood the test of application over long periods of time. Even our short period of application has found many of these rules to be imperfect, and proper modifications in the rulings are the subject of almost continual study. If the application of the funding idea to repair costs can be shown to be economically sound and just, and to the best interests of all concerned, I can see no reason why a proper presentation of the idea should not result in a modified ruling that would permit of carrying a repair fund over from year to year. We certainly do not have to wipe out our depreciation funds every year, and why should we be required to wipe out other funds of equal economic soundness.

I can not see why a repair fund should offer an alibi for unnecessary repairs to the operating departments. The costs of repairs would be turned in through regular channels just as at present, and the repair fund would be enlarged or reduced as circumstances dictated by the auditing departments. Unnecessary costs would still be reported and could not be covered up any more than they are at present.

I would like to ask Mr. Dupka if the government requires the balancing and wiping out of repair funds at the end of each year.

W. H. Dupka: I do not know that any fixed policy has been determined by the federal income tax department, but if repairs applicable to a current year were funded and major items that pertain to a longer period were charged to depreciation reserve, I do not believe there would be any objections from that source.

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of

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April, 1930 Vol. 46, No. 4

PART 2

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Corrected to Jan. 1st, 1930

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Student Juniors	5	2	7
	1311	274	1585

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The Board of Direction on May 11, 1907 authorized the award, each year, of two medals gold and silver, to Members of the Society under the following rules, which were revised May 28, 1915 and December 15, 1925.

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1. There will be two medals, one of gold and the other of silver.

2. The awards are to be made by the Board of Direction on the recommendation of a committee of three, appointed by the President, from its members.

3. Medals shall be open for competition to all authors of papers. No person shall receive both medals in any one year. In case of award to a paper of joint authorship, separate medals shall be given to each author.

4. The medals shall be awarded to the authors of the best and second best papers presented during the year.
   The value of the papers shall be judged on the following points:
   - (a) Value to engineering profession.
   - (b) Originality of subject matter.
   - (c) Treatment.

5. The Directors may refuse to grant either or both medals in any one year when no paper deemed worthy of award is presented.

6. Papers presented at regular meetings of the Society or its Sections and which are printed in the Proceedings only are eligible for award.

7. The medals shall be presented at some meeting of the General Society, subsequent to the annual meeting.

8. The recipient's name and the year of award shall be engraved on each medal, and suitable designation of Medalist shall be made annually in the published List of Members and their names enrolled on a roll of honor displayed in the Society Rooms.

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RIDDLE, WALTHER	1911	'09 '10			'07 '08
RIDINGER, C. W.			'01 '02 '03 '04		
*ROBERTS, T. P.	1891				'88 '89 '94 '95
RODD, THOMAS		'81 to '84			'80
*SCAIFE, W. L.	1890	'88 '89			'86 '87
SCHATZ, FRED C.					'19 '20 '21
SCHAUER, F. F.					'30
*SCHELLENBERG, F. C.					'07 '08 '09
SCOTT, CHARLES F.	1902	'00 '01			'98 '99
SCOTT, GUSTAVE					'98
SKINKLE, W. B.					'29 '30
SMITH, M. V.					'82
*SNYDER, W. E.	1918	'16 '17			'13 '14 '15
SPELLER, F. N.					'20
SPELLMIRE, WALTER B.	1925	'23 '24			'19 '20 '21
STAHL, K. F.					'95 '96
STROBEL, C. L.		'85 '86			
STUCKI, A.	1915	'13 '14		1917 to date	'11 '12
*SWENSSON, EMIL	1897	'95 '96			'93 '94
*TAYLOR, E. B.	1886				'87 '88
TAYLOR, S. A.	1913	'12			'09 '10 '11
*TAYLOR, SELWYN M					'03
TERRY, C. D.					'22
*THAW, WILLIAM JR.		'82			'85 '88
TRESCHOW, K. F.			1917 to date		
UNGER, JOHN S.					'15 '16
WELDIN, W. A.					'24 '25 '26
WHITEHEAD, WILLIS					'04 '05'10 '11
*WICKERSHAM, S. M.			'86 to '90		
*WILKINS, W. G.	1896	'94 '95			'90 '91
WILLIAMS, J. I		'80			
WILSON, H. D.					'19
WORTHINGTON, CHARLES					'04
*YARDLEY, EDMUND			'07		
ZIMMERMAN, W. F.			'85		

*Deceased.

GENERAL INFORMATION

Meetings: Regular meetings of the Society are held on the third Tuesday of each month, except July and August.

Civil Section Meetings: First Tuesday in January, March, May, September and November.

Electrical Section Meetings: Second Tuesday each month except June, July and August.

Illuminating Engineers' Section: Bi-Monthly, January, March, May, September and November.

Mechanical Section Meetings: First Tuesday in February, April, June, October and December.

Mineral Industries Section Meetings: Fourth Tuesday in January, March, May, September and November.

Practising Engineers' Section Meetings: Third Wednesday of February, April, June, October and December.

Steel Works Section Meetings: Fourth Tuesday in February, April, June, October and December.

Annual Meeting of the Society: Third Tuesday in January.

The Society rooms and Library are open every day, except Sundays, Memorial Day, Fourth of July, Labor Day, Thanksgiving, Christmas and New Years from 8:30 A. M. to 10:30 P. M.

Publications: The Society issues a publication, Proceedings, ten months in the year, containing the original papers on technical subjects read before the Society, together with all discussion offered in connection therewith; minutes, reports, engineering data and other matters of record. The Proceedings are furnished to the entire membership.

Reprints from this publication, which is copyrighted, may be made by any other publication on condition that the full title of paper, name of author, page reference, and date of presentation to the Society are given. This does not apply to matter under Engineering Data, republication of which is reserved to the Society.

No paper read before the Society shall be published in any magazine or journal before its appearance in the Proceedings, and no paper previously published shall be published in the Proceedings without the sanction of the Board.

The annual subscription to the Proceedings is $5.00. Single copies 50c each. To public libraries and colleges, which agree to bind and catalog, the subscription price is $3.00 per year.

A List of Members of the Society is published annually.

Professional Papers: All persons, whether members of the Society or not, are invited to send in papers and discussions on engineering subjects. All papers and discussions are under the supervision of the Publication Committee and are subject to proper editing.

Admission to Membership: The membership of the Society consists of Honorary Members, Members, Associate Members, Associates, Juniors and Student Juniors. The qualifications for membership are given in Article I of the By-Laws.

The Entrance Fee for Members, Associate Members and Associates is $10.00; Juniors and Student Juniors are not required to pay this fee. The annual dues for Resident Members, Associate Members and Associates are $20.00, Resident Juniors $10.00, and Resident Student Juniors $3.00; for Non-resident Members, Associate Members and Associates $10.00, for Non-resident Juniors $7.50, and for Non-resident Student Juniors $3.00. Payment of dues for the unexpired quarters of the year only is required on entrance to the Society.

Society Pins: The Society Emblem, a small reproduction of the Seal of the Society, in blue enamel mounted in solid gold, may be obtained in either the pin or button style and will be mailed on receipt of $3.00 covering cost.

Exchange of House Privileges: House and Library privileges are exchanged, on presentation of membership cards, with the following Engineering Societies:

American Society of Civil Engineers, New York.
American Society of Mechanical Engineers, New York.
American Institute of Electrical Engineers, New York.
American Institute of Mining & Metallurgical Engineers, New York.
Boston Society of Civil Engineers, Boston, Mass.
Brooklyn Engineers' Club, Brooklyn, New York.
Engineering Society of Buffalo, Buffalo, N. Y.
Civil Engineers' Society of St. Paul, St. Paul, Minn.
Cleveland Engineering Society, Cleveland, Ohio.
Detroit Engineering Society, Detroit, Mich.
Engineers' and Architects' Club, Louisville, Ky.
Engineering Institute of Canada, Montreal, Canada.
Engineers' Club of Baltimore, Baltimore, Md.
Engineers' Club of Dayton, Dayton, O.
Engineers' Club of Kansas City, Kansas City, Mo.
Engineers' Club of Minneapolis, Minneapolis, Minn.
Engineers' Club of Philadelphia, Philadelphia, Pa.
Engineers' Club of St. Louis, St. Louis, Mo.
Engineers' Club of Seattle, Seattle, Wash.
Engineers' Club of Toronto, Toronto, Canada.
Engineers' Society of Pennsylvania, Harrisburg, Pa.
Louisiana Engineering Society, New Orleans, La.
Rochester Engineering Society, Rochester, N. Y.
Society of American Military Engineers, Washington, D. C.
Technology Club of Syracuse, Syracuse, N. Y.
Technical Society of the Pacific Coast, San Francisco, Cal.
Toledo Society of Engineers, Toledo, O.
Western Society of Engineers, Chicago, Ill.

MEDAL AWARDS FOR PAPERS

1907

HENRY SEWALD PRICHARD

GOLD MEDAL

"PROPORTIONING OF STEEL RAILWAY BRIDGE MEMBERS"

THOMAS PASCHAL ROBERTS

SILVER MEDAL

"FLOODS AND MEANS OF THEIR PREVENTION IN OUR WESTERN RIVERS"

1912

FREDERICK G. GASCHE

SILVER MEDAL

"THEORY OF STEAM ACCUMULATORS AND REGENERATIVE PROCESSES"

1915

ARTHUR W. THOMPSON

GOLD MEDAL

"MAGNOLIA CUT-OFF IMPROVEMENT ON THE BALTIMORE & OHIO RAILROAD"

BENJAMIN FELAND GROAT

SILVER MEDAL

"PITOT TUBE FORMULAS—FACTS AND FALLACIES"

1916

JOHN A. HUNTER

SILVER MEDAL

"TESTS ON A RECENT TYPE OF CHAIN GRATE STOKER AND NEW METHODS OF BAFFLING STIRLING BOILERS"

1917

A. L. HUMPHREY

GOLD MEDAL

"MOBILI ZATION OF MATERIAL AND INDUSTRIAL RESOURCES"

ROBERT LINTON

SILVER MEDAL

"THE WINDOW GLASS MACHINE"

1918

JAMES STEWART MARTIN

SILVER MEDAL

"NEW AND LITTLE KNOWN METHODS OF THE CALCULATION OF BEAMS, GIRDERS, AND ARCHES"

1919

ARTHUR E. CROCKETT

SILVER MEDAL

"CAST STEEL ANCHOR CHAIN"

1920

MORRIS KNOWLES and MAURICE R. SCHARFF

SILVER MEDALS

Joint Paper

"REGIONAL PLANNING IN THE PITTSBURGH DISTRICT"

1921

J. BRADLEY MANDEVILLE

SILVER MEDAL

"AERIAL PHOTOGRAPHY AS APPLIED TO SURVEYING."

1922

JAMES STEWART MARTIN

SILVER MEDAL

"STRUCTURAL ENGINEERING PROBLEMS IN TRANSMISSION —LINE CONSTRUCTION"

1923

J. C. HOBBS and L. W. HELLER

SILVER MEDALS

Joint Paper

"PULVERIZED FUEL FOR LARGE BOILERS"

1924

E. K. MORSE

SILVER MEDAL

"SOLUTION OF THE TRANSPORTATION, PARKING, AND FLOOD PROBLEMS OF PITTSBURGH".

LIFE MEMBERS

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LIST OF MEMBERS

ALPHABETICAL LIST OF MEMBERS OF ALL GRADES

*A star placed before the name of a member indicates that he has contributed one or more papers to the Society's Proceedings.

Ackenheil, Alfred A. (Jan. 1908; Feb. 1925) Engr, John F. Casey Co, Box 1753, Pittsburgh, Pa; h, 3102 Landis St, Pittsburgh, Pa.... .... **Sterling 1400**

Acker, Albert J. (March 1925) Sales Engr, Manning, Maxwell & Moore, Inc, Park Bldg; h, 427 Forest Ave, Bellevue, Pittsburgh, Pa....... .... **Atlantic 6330**

Adair, William R. (**Associate**) (Dec. 1924) Supt, Pittsburgh, Mars & Butler Rwy. Co; h, Mars, Pa.......... **Mars 28–R-3**

Adams, Henry Clay (Oct. 1922) 5304 St. James Terrace, Pittsburgh, Pa.

Affelder, Louis J. (July 1902) Div. Contracting Mgr, American Bridge Co, 1531 Frick Bldg; h, 5825 Bartlett St, Pittsburgh, Pa.... **Atlantic 4300**

AFFELDER, WILLIAM L. (**President**) (Oct. 1913) V. P, Hillman Coal & Coke Co, 2306 First National Bank Bldg, Pittsburgh, Pa; h, 12 Dinsmore Ave, Crafton, Pittsburgh, Pa.......... **Atlantic 2620**

Agthe, Fred Thomas (June 1924) Sales Engr, Allis-Chalmers Mfg. Co, Milwaukee, Wis; h, 1400 Wisconsin Ave, Milwaukee, Wis.

Aichberger, Carl (April 1927) Dist. Sales Mgr, International Oxygen Co, Verona, Pa; h, 728 Washington Ave, Oakmont, Pa.... **Oakmont 129**

ALEXANDER J. IRVIN (**Chairman Electrical Section**) (Feb. 1924) Director Power and Steam Survey Section, Philadelphia Company, 435 Sixth Ave, Pittsburgh, Pa; h, 1204-5th Ave, Coraopolis, Pa. .... **Grant 4300**

★**Alford, Newell Gilder** (Oct. 1922) V. P, Eavenson, Alford & Hicks, 1300 Union Trust Bldg; h, 7145 Meade St, Pittsburgh, Pa...... .... **Atlantic 3939**

Allan, David W. (Feb. 1924) Sales Mgr, Industrial Div, Fairmont Mining Machinery Co, 517 Clark Bldg; h, 1206 Rebecca Ave, Wilkinsburg, Pittsburgh, Pa.......... **Atlantic 9229**

Allderdice, Norman (June 1915) Pres, Arch Machinery Co, Inc, 1001 Park Bldg; h, 5727 Wilkins Ave, Pittsburgh, Pa.......... **Atlantic 6430**

Allderdice, Taylor (Feb. 1917) 1001 Park Bldg; h, 5727 Wilkins Ave, Pittsburgh, Pa.......... **Atlantic 6430**

List of Members

Allen, Harvey (Feb. 1903) Consulting Engineer, Private Practice; h, 347 Columbia Ave, West View, Pittsburgh, Pa...... **Wellington 1163-R**

Allen, James Gillespie (Associate Member) (June 1926) Radio Engr, Duquesne Light Co, 800 Duquesne Bldg, Cecil Way, Pittsburgh; h, 123 Harrison Ave, Avalon, Pittsburgh, Pa... **Grant 4300 Ext. 533**

Allen J. Wallace (Dec. 1928) Chief Mechanical Engineer, Clairton By-Product Coke Works, Carnegie Steel Company, Clairton, Pa; h, 540 Mitchell Avenue, Clairton, Pa.................... **Clairton 5**

Allen, Lewis C. (Associate) (March 1928) Sales Engr, Fairbanks Morse & Co, Cleveland, Ohio; h, Emerson Ave, Parkersburg, W. Va.

Allewelt, Robert (March 1929) Sales Engineer, General Electric Co, 1317 Oliver Building; h, 531 Collins Ave, Apt. 12, Pittsburgh, Pa..... .... **Atlantic 6400**

Allison, John Harold (May 1921) Vice Pres, E. J. Deckman Co, 902 Oliver Bldg; h, 605-A Worth St, Pittsburgh, Pa............ **Atlantic 1843**

Altsman, William H. (June 1928) Mech. Engr, Pittsburgh, Harmony, Butler & New Castle R. R, 602 Benedum-Trees Bldg; h, 67 Watsonia Blvd, N. S, Pittsburgh, Pa.......................... **Court 0194**

Anderson, Burt T. (Associate Member) (Nov. 1928) Asst. to Vice President, Union Switch & Signal Co, Swissvale, Pa; h, 6944 Thomas Blvd, Pittsburgh, Pa.................... **Penhurst 0880-Ext. 208**

Anderson, Charles H. (Oct. 1925) Estimator Jones & Laughlin Steel Corp, Aliquippa, Pa; h, 2112 Arlington Ave, Mt. Oliver Sta, Pittsburgh, Pa.. **Court 3240**

Anderson, Harry Clifford (Oct. 1927) Chief Engr, American Sheet Opener Co, and Blastco Corp; h, R. F. D. No. 1, Bradley, Mich.

Anderson, Robert (Feb. 1919) Steel Works Engr, Carnegie Steel Co, Homestead, Pa; h, 804 Hiland Ave, Coraopolis, Pa............ .... **Homestead 2603**

Anderson, Walker (Associate) (Dec. 1926) Sales Engr, General Electric Co, Oliver Bldg; h, 1421 Walnut St, Edgewood, Pittsburgh, Pa....... .... **Atlantic 6400**

Andrews, J. R. (March 1929) Designer, Aetna Standard Engineering Co, 1400 Chamber of Commerce Bldg, Pittsburgh, Pa; h, 700 Fourth St, Beaver, Pa................................. **Atlantic 9000**

Andrews, John, Jr. (May 1929) Central District Manager, Westinghouse Electric & Manufacturing Company, 1800 Grant Building; h, 5556 Wellesley Ave, Pittsburgh, Pa............ **Atlantic 8400**

Andrews, Roger W. (May 1921) Assistant to the President, Blaw-Knox Co. P. O. Box 915, Pittsburgh, Pa; h, Delafield Heights, Aspinwall, Pittsburgh, Pa............................ **Sterling 2700**

List of Members

Andrews, William W. (June 1921) Civil & Mining Consulting Engr, 1200 Jones Law Bldg, Pittsburgh, Pa; h, 430 Beechwood Ave, Carnegie, Pa..**Court 0275**

Angle, James Macfarlane (Oct. 1919) Assoc. Highway Bridge Engr, U. S. Bureau of Public Roads, P. O. Box J, Shepperd Bldg; h, 201 Clayton St. Montgomery, Ala.

Angstrom, C. J. (May 1921) Mech. Engr, Mackintosh-Hemphill Co, Point Bldg, Pittsburgh, Pa; h, 237 Forest Ave, Bellevue, Pittsburgh, Pa. ....**Court 3862**

Archer, Arthur A. (March 1928) Asst. Engr, Pittsburgh Coal Co, 1012 Oliver Bldg; h, 924 Timberland Ave, S. H. Sta, Pittsburgh, Pa. ....**Atlantic 2181**

Archer, Robert B. (**Junior**) (March 1927) Bridge Designer, T. J. Wilkerson, County Engineer, Court House, Beaver, Pa; h, 329 College Avenue, Beaver, Pa.............................**Beaver 1450**

Arensberg, Francis Louis (June 1911) Pres, Vesuvius Crucible Co, Box 47, Swissvale, Pa; h, 4739 Bayard St, Pittsburgh, Pa..**Brandywine 0107**

Armel, James Paul (June 1922) Sales Engr, 611 Bessemer Bldg, Pittsburgh, Pa; h, 466 Biddle Ave, Wilkinsburg, Pittsburgh, Pa..**Atlantic 7084**

★**Arras, John W.** (Nov. 1888) Senior Engr, U. S. Engineer Department, 1507 Keenan Bldg, Pittsburgh; h, Woodlawn Drive, Coraopolis, Pa..**Atlantic 5958**

Arrott, James W. Jr. (March 1892) Treasurer, James W. Arrott, Ltd, Arrott Bldg, Pittsburgh; h, Sewickley, Pa............**Court 2640**

Arrowsmith, John C. (April 1926) 1st Lieut. Corps of Engineers, U. S. Army, Carnegie Institute of Technology; h, 5454 Wilkins Ave, Pittsburgh, Pa.......................................**Mayflower 2600**

Arvidson, Carl Gustaf (Dec. 1926) Designer, Allegheny Steel Co, Brackenridge, Pa; h, Box 163, Tarentum, Pa..............**Tarentum 1000**

Aston, James (March 1916) Professor of Mining & Metallurgy, Carnegie Institute of Technology, Pittsburgh; h, 7315 Perrysville Ave, Ben Avon, Pittsburgh, Pa........................**Mayflower 2600**

Atcherson, Ralph W. H. (May 1915) Blast Furnace Supt, Illinois Steel Co; h, 667 Van Buren St, Gary, Ind.

Atkinson, George H. (Nov. 1924) Chf. Engr, G. H. Atkinson Co, 73-8th Ave; h, 150 W. 106th St, New York, N. Y.

Auburn, Basil J. (**Associate**) (Dec. 1924) Control Engineer, Westinghouse Elec. & Mfg. Co. East Pittsburgh, Pa; h, 117 Pennwood Ave, Edgewood, Pittsburgh, Pa........................**Brandywine 1500**

Auchmuty, R. Laird (March 1928) Mining Engr, Eavenson, Alford & Hicks, 1300 Union Trust Bldg; h, 1228 Kelton Ave, Dormont, Pittsburgh, Pa.................................**Atlantic 3939**

Augustine, Charles Edward (March 1909) Assoc. Fuel Engr, U. S. Bureau of Mines, 4800 Forbes St; h, 7100 Upland St, Pittsburgh, Pa..**Mayflower 4500**

★**Auld, Elgie C.** (June 1915) Chief Engr, H. C. Frick Coke Co, Box 71, Scottdale, Pa; h, 1201 Loucks Ave, Scottdale, Pa...**Scottdale 620**

Austin, Walter Merville (March 1919) Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 1527 Berkshire Ave, South Hills, Pittsburgh, Pa..................................**Brandywine 1500**

Babb, Joseph E. (June 1922) Mgr, Falk & Co, Carnegie, Pa; h, 5008 Friendship Ave, Pittsburgh, Pa....................**Carnegie 860**

Bacharach, Herman (Nov. 1905) Pres, Bacharach Industrial Instrument Co, 7000 Bennett St; h, 6336 Phillips Ave, Pittsburgh, Pa...**Montrose 0703**

Bachtel, Samuel Rowan (Sept. 1903; Nov. 1916) Secy. & Treas, Guibert Steel Co, 1716 Youghiogheny Ave, Corliss Sta; h, 4012 Windsor St, Squirrel Hill, Pittsburgh, Pa....................**Federal 2960**

Baer, Harry L. (March 1925) Pres, Water Treatment Co. of America, 2716 Grant Bldg; h, 2962 Crosby Ave, Dormont, Pittsburgh, Pa...**Atlantic 5490**

Bailey, John M. (May 1917) Pres, Standard Inspection Co, Martin Bldg, 119 Federal St, Pittsburgh, Pa; h, 916 California Ave, Avalon, Pittsburgh, Pa..................................**Fairfax 4982**

Bain, George Frederick (Associate) (Nov. 1926) District Mgr, Copperweld Steel Co, Room 526, 30 Church St, New York, N. Y.

Baln, J. G. (April 1923) Care of E. W. Bliss, Co, Salem, Ohio; h, 818 Farragut St, E. E. Pittsburgh, Pa.

Baird, Hazen Virgil (Junior) (June 1928) Draftsman, Blum, Weldin & Co, 417 Grant St, Pittsburgh, Pa; h, 16 Oberlin Ave, Swarthmore, Pa. ....**Court 4997**

★**Baker, David** (Jan. 1926) Consulting Engineer, 1011 Chestnut St, Philadelphia, Pa; h, Rosemont, Pa.

Baker, David Jr. (Jan. 1926) Metallurgical Engineer, 1011 Chestnut St, Philadelphia, Pa; h, Orchard Way, Rosemont, Pa.

Baker, John Marion (May 1927) Chief Engr, Hydrolithic Waterproofing Co, 725 Grant Bldg; h, 6308 Stanton Ave, Pittsburgh, Pa...**Atlantic 1890**

Baker, Thomas Stockham (Sept. 1924) Pres, Carnegie Institute of Technology, Schenley Park; h, Pittsburgh Athletic Association, Pittsburgh, Pa..................................**Mayflower 2600**

Baker, Walter H. (Sept. 1916) Secy, Treas, & Gen. Mgr, Universal Steel Co, Bridgeville, Pa; h, 238 E. Wheeling St, Washington, Pa...**Bridgeville 34**

Bakewell, Donald Campbell (April 1913) Pres. Duquesne Steel Foundry Co, Union National Bank Bldg, Pittsburgh, Pa; h, Sewickley, Pa. ....**Court 4938 or Coraopolis 505**

Ballard, Douglas Keene (Associate) (June 1923) Salesman, Kier Fire Brick Co, 1844 Oliver Bldg, Pittsburgh, Pa; h, Highland Terrace, Aspinwall, Pittsburgh, Pa........................**Atlantic 0957**

Baltzell, Will H. (Dec. 1892) Chf. Engr, Canadian Steel Corporation Ltd; h, Ojibway, Essex County, Ontario, Canada.

Bankson, Ellis E. (April 1926) Member Firm, The J. N. Chester Engineers, Clark Bldg; h, 125 Hemphill St, N. S, Pittsburgh, Pa...... ....**Atlantic 1140**

Barchfeld, Herman C. (March 1917) Mech. Engr, Concrete Products Co. of America, 712 Diamond Bank Bldg; h, 2046 Brownsville Road, Pittsburgh, Pa........................**Atlantic 3841**

Barnes, Hugh Cooper (Jan. 1911) Mech. Engr, American Rolling Mill Co, Middletown, O.

Barnes, Joseph F. (Nov. 1929) Asst. Secy. Eljer Co, Ford City, Pa; h, R. F. D. No. 3, Kittanning, Pa.

Barney, Harry (Associate Member) (April 1916) Pres. & Treas, Barney Machinery Co, Inc, Koppers Bldg; h, 1000 N. Highland Ave, Pittsburgh, Pa........................**Atlantic 4116**

Barnsley, George T., Jr. (Associate Member) (June 1914) Draftsman; h, Grace Dodge Hotel, Washington, D. C.

Barr, J. Carroll (Dec. 1924) Contracting Engineer, 616 Oliver Bldg; h, 4727 Wallingford St, Pittsburgh, Pa........................**Atlantic 1825**

Barrett, Cecil Huitt (Associate Member) (May 1925) Asst. Designing Engr, Bureau of Engineering, City of Pittsburgh, 537 City-County Bldg; h, 3315 Francisco St, Pittsburgh, Pa........**Atlantic 3900-Line 158**

Barrett, James Marsh (May 1919) Pres, Polar Water Co, 939 West North Ave, Pittsburgh, Pa; h, Dutch Ridge Road, Beaver, Pa..**Cedar 8000**

Barrett, J. M. (March 1928) Mgr. Regulator Dept, Bailey Meter Co, Ivanhoe Road; h, 3385 Fairmount Blvd, Cleveland Heights, Cleveland, Ohio.

Barry, Louis T. (Associate Member) (April 1924) Salesman, Electric Service Supplies Co, 1123 Bessemer Bldg; h, University Club, Pittsburgh, Pa........................**Atlantic 0550**

Barry, T. J. (March 1924) Manufacturers' Representative, Park Bldg; h, 222 Parkman Ave, Pittsburgh, Pa........................**Atlantic 5193**

Bartholomew, Tracy (Feb. 1924) Mgr. of Research and Tests, Duquesne Slag Products Co, 704 Diamond Bank Bldg; h, 6668 Woodwell St, Pittsburgh, Pa........................**Atlantic 3841**

Batchelar, Eugene Croker (Feb. 1912) Mgr. Motch & Merryweather Machinery Co, 1315 Clark Bldg; h, 921 College Ave, Pittsburgh, Pa.. **Atlantic 3985**

Bates Robert P. (Dec. 1928) Engineering Asst, Bell Telephone Co. of Pennsylvania, 630 William Penn Way; h, 1140 Tennessee Ave, Dormont, Pittsburgh, Pa......................... **Official 0050**

Bathgate, Owen Hamill (Dec. 1928) Dist. Sales Mgr, Carrier-Lyle Corp, 1404 Clark Bldg; h, 558 East End Ave, Pittsburgh, Pa... **Atlantic 5656**

Baton, George Scott (Nov. 1916) Pres, Geo. S. Baton & Co, 2413 First National Bank Bldg; h, 326 S. Graham St, Pittsburgh, Pa.. **Atlantic 1576**

Bauer, Ralph G. (Oct. 1926) Engineering Secy, The Koppers Construction Co, Koppers Bldg, Pittsburgh; h, 46 S. Bryant Ave, Bellevue, Pittsburgh, Pa.................................. **Atlantic 6240**

Baxter, James W. (May 1919) Mech. Engr, National Tube Co, Ellwood Works, Ellwood City, Pa.

Bay, Frederick R. (Dec. 1923) Vice-Pres, The Bay Co, Bridgeport, Conn; h, 45 Prospect Place, New York, N. Y.

Beach, Willard J. (Jan. 1903) Engineer, Heyl & Patterson, Pittsburgh, Pa; h, Box 97, Perrysville, Pa........................... **Court 0753**

Beatty, Floyd A. (Nov. 1925) Chf. Eng, Lewis Fdry. & Machine Co, Box 1591, Pittsburgh, Pa; h, 3306 Allendale St, Corliss Station, Pittsburgh, Pa.................................. **Federal 3311**

Beatty, John David (Associate Member) (Feb. 1925) Secretary, Mining and Metallurgical Advisory Boards, Carnegie Institute of Technology; h, 505 S. Lang Ave, Pittsburgh, Pa........ **Mayflower 2600**

Beck, Herman (June 1927) Designer, Carnegie Steel Co, Duquesne Works; h, 11 S. 5th St, Duquesne, Pa.................. **Duquesne 5153**

Beck, Wesley J. (Feb. 1925) Director of Research, The American Rolling Mill Co; h, 401 Alameda, Middletown, O.

Becker, Joseph (Jan. 1921) Vice Pres, and Gen. Mgr, The Koppers Construction Co, 1550 Koppers Bldg, Pittsburgh, Pa; h, Waldheim Road, Aspinwall, Pittsburgh, Pa.................. **Atlantic 6240**

Becker, Mathias (Associate Member) (Nov. 1922) Civil & Mining Engr; h, 375 Washington Ave, Leechburg, Pa......... **Leechburg 275-W**

Beckwith, Homer E. (Associate Member) (April 1929) Dist. Manager, Pitometer Co, Yoffee Bldg, Harrisburg, Pa; h, 2014 Mulberry Street, Harrisburg, Pa.

Behney, C. C. (Dec. 1924) Dist. Repr, Simplex Valve & Meter Co, 718 Empire Bldg; h, 2832 Broadway, Dormont, Pittsburgh, Pa... **Grant 5476**

Bell, Frank B (May 1921) Pres, Edgewater Steel Co, Box 249; h, 808 Devonshire St, Pittsburgh, Pa.................... **Oakmont 280**

Bell, George Gordon (April 1921) Mgr. Power Development, West Penn Electric Co, 14 Wood St; h, Pittsburgh Athletic Association, Pittsburgh, Pa.................................... **Court 4106**

Bellows, Sidney R. (**Associate Member**) (Feb. 1925) Fire Protection Engr, Blackstone Mutual Fire Ins. Co, 1000 Grosvenor Bldg; h, 23 Tuzon Ave, Providence, R. I.

Benedict, John Blakesley (**Associate**) (Feb. 1926) Agent, The American Brass Co, 519 Statler Bldg, Boston, Mass; h, 12 Commonwealth Ave, Boston, Mass.

Benn, Charles Leasure (Feb. 1925) Sales Engr, Peerless Heater Co, 5602 Baum Blvd; h, 227 Ruxton St, Pittsburgh, Pa....... **Atlantic 0481**

Benner, Jacob W. (Sept. 1911) Supt. Employment, Safety & Welfare, Carnegie Steel Co, Homestead Steel Works, Munhall, Pa; h, 415 Neville St, Pittsburgh, Pa...................... **Homestead 2603**

Bennett, Charles Wilbur (April 1920) Vice Pres, American Sheet & Tin Plate Co, 1321 Frick Bldg; h, 6300 Darlington Road, Pittsburgh, Pa.. **Atlantic 1300**

Berg, Hakon Axel (Nov. 1904) care of Sloss, Sheffield Steel & Iron Co, Birmingham, Ala.

★**Berg, John Daniel** (April 1914) V. P, The Dravo Contracting Co, Dravo Bldg, 300 Penn Ave, Pittsburgh; h, Beaver Road, Glen Osborne, Pa.. **Court 5400**

Berg, W. Edward (April 1898) Chf. Engr, Colorado Fuel & Iron Co, Pueblo, Col.

Berger, John N. (June 1927) Mech. Draftsman, United Engrg. & Fdry. Co, 2426 Farmers Bank Bldg; h, 196 Locust St, Emsworth, Pittsburgh, Pa.................................... **Atlantic 0863**

Berger, Newell James (**Associate Member**) (Oct. 1928) Owner, The Water Development Co, 207 Investment Bldg, Pittsburgh, Pa; h, 319 Forest Avenue, Ben Avon, Pittsburgh, Pa.... **Atlantic 6050**

Bernstein, Lester (**Associate Member**) (May 1925) Mgr, Commercial Development Dept, Philadelphia Company, 435-6th Ave; h, 5678 Phillips Ave, Squirrel Hill Sta, Pittsburgh, Pa........ **Grant 3200**

Bickel, William D. (Dec. 1922) Pgh. District Repr, The Allen-Sherman-Hoff Co; Ross Heater & Mfg. Co, 508 State Theatre Bldg; h, 418 S. Aiken Ave, Pittsburgh, Pa................. **Atlantic 1565**

Bigelow, Charles Glenford (May 1922) Research Engineer, Inland Steel Co, Indiana Harbor, Ind; h, 1644 S. Herman St, Hammond, Ind.

★**Biggert, Florence C. Jr.** (April 1903) Vice Pres, and Senior Engineer, United Engrg. & Fdry. Co, 23rd Floor, Farmers Bank Bldg, Pittsburgh, Pa; h, 108 Hawthorne Ave, Crafton, Pittsburgh, Pa... **Atlantic 0863**

Billheimer, C. R. (Feb. 1927) Elec. Engr, West Penn Power Co, 14 Wood St; h, 428 South Ave, Wilkinsburg, Pittsburgh, Pa..**Court 4106**

Bingay, Robert V. (Dec. 1926) President, Stove & Range Co, of Pittsburgh, Preble Ave, N. S; h, Perrysville, Pa.................**Cedar 1520**

Binnall, Frederick Clifford (March 1923) Dusseldorf, Germany.

Bishop, Frederick Lendall (Jan. 1912) Head Department of Physics, University of Pittsburgh; h, Pittsburgh, Pa........**Mayflower 3500**

Bisler, Walter Edward (Associate Member) (Oct. 1924) Sales Engr, Combustion Engineering Corp, 1606 First National Bank Bldg; h, 229 Beverly Road, Mt. Lebanon, Pittsburgh, Pa.......**Atlantic 1511**

Black, Robert Moffitt (May 1921) Professor and Head of Dept. Mining, University of Pittsburgh; h, 3732 Dawson St, Pittsburgh, Pa...**Mayflower 3500**

Blair, George Sheppard (May 1927) Supt. of Bldgs, Bell Telephone Co. of Penna, 416 Seventh Ave, Pittsburgh, Pa; h, 123 S. Harrison Ave, Bellevue, Pittsburgh, Pa..........................**Official 0050**

Blaisdell, Allen H. (June 1929) Associate Prof. of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa; h, 939 Trenton Ave, Wilkinsburg, Pittsburgh, Pa......**Mayflower 2600**

Blake, A. Wade (October 1929) Sales Engineer, Consolidated Ashcroft Hancock Co, 1411 Park Bldg; h, 2938 Mattern Avenue, Dormont, Pittsburgh, Pa.................................**Atlantic 6330**

Blakeslee, Doraf Wilmot (April 1927) Illuminating Engineer, Pittsburgh Reflector Company, Bowman Building; h, 1211 Morningside Ave, Pittsburgh, Pa.................................**Court 0571**

Blanton, Hennen J. (Dec. 1924) Asst. Engineer, Boiler Division, Combustion Engineering Corp, 200 Madison Ave, New York, N. Y; h, 8829 Fort Hamilton Parkway, Brooklyn, N. Y.

Blenko, Walter J. (Dec. 1924) Member of Firm, Byrnes, Stebbins, Parmalee & Blenko, 1319 Farmers Bank Bldg; h, 4338 Luster St, Pittsburgh, Pa...**Atlantic 1609**

Blest, Minot C. (Dec. 1902) Chief Engr, Pressed Steel Car Co, Farmers Bank Bldg, Pittsburgh, Pa; h, 1011 California Ave, Avalon, Pittsburgh, Pa...................................**Federal 0740**

Blickle, Herman Renner (May 1910) V. P, Fort Pitt Bridge Works, Oliver Bldg, Pittsburgh, Pa........................**Atlantic 0654**

Bloom, Frederick Sturate (Oct. 1924) Rate Engineer, Pittsburgh Group, Columbia Gas & Electic Corp, 800 Union Trust Bldg; h, 380 Orchard Drive, Mt. Lebanon, Pittsburgh, Pa,.......**Atlantic 9320**

Bloomquist, O. A. (March 1926) Pittsburgh Life Bldg, Pittsburgh, Pa.

★**Blum, Louis P.** (Jan. 1903) Partner, Blum, Weldin & Co, Bakewell Bldg, 417 Grant St; h, 3070 Watson Entrance, N. S, Pittsburgh, Pa .... **Court 4997-8**

Boardman, Charles Slauson (Feb. 1929) Contracting Engr, Jones & Laughlin Steel Corp, Steel Piling Dept; h, 520 St. James Place, Pittsburgh, Pa.. **Court 3240**

Bode, John Henry (Dec. 1915) Pres, The Wellman-Seaver-Morgan Co, 7000 Central Ave; h, 2933 Lee Road, Shaker Heights, Cleveland, O.

Bohn, Donald Ivan (Dec. 1928) Electrical Engineer, Aluminum Co. of America, 2400 Oliver Bldg; h, 124 Newburn Drive, Mt. Lebanon, Pittsburgh, Pa.. **Atlantic 4545**

Bole, Harry A. (Sept. 1918) Engr. in charge Drafting Room, Carnegie Steel Co, 1500 Carnegie Bldg; h, 148 S. Bryant Ave, Bellevue, Pittsburgh, Pa.. **Atlantic 5100**

Bonsall, Judson (May 1927) Supt. Compressing Stations, Equitable Gas Co. and Pittsburgh & West Virginia Gas Co, 604 Union Bank Bldg; h, 509 Milford St, Clarksburg, W. Va.

Boothman, Dale Maxwell (Jan. 1921) M. E, Research Bureau, Aluminum Co. of America, New Kensington, Pa; h, 223-8th Ave, Oakmont, Pa.. **New Kensington 8**

Borg, John Edward (May 1925) Chief Draftsman Julian Kennedy, Jr, 1217 Bessemer Bldg; h, 232 Martsolf Ave, West View, Pittsburgh, Pa. .... **Atlantic 7730**

Botsai, Louis Roderick (Nov. 1923) Central Industrial Manager, Westinghouse Elec. & Mfg. Co, 1825 Grant Bldg; h, Clover Club, 6744 Penn Ave, Pittsburgh, Pa.. **Atlantic 8400**

Bowers, Edwin C. (**Associate**) (March 1912) Gen. Mgr, The Edward Ford Plate Glass Co; h, Rossford, Ohio.

Bowman, Franklin Meyer (April 1893) V. P, Blaw Knox Co, Box 915, Pittsburgh; h, 1234 N. Highland Ave, Pittsburgh, Pa.... **Sterling 2700**

Boyd, John Ridinger (June 1912; Nov. 1922) Designing Engr, P.&L.E.R.R. Room 500, P.&L.E. Terminal Bldg; h, 1454 Alabama Ave, South Hills Sta, Pittsburgh, Pa.................... **Court 3201-Ext. 181**

Boyd, Marcus (**Associate**) (April 1924) Pres, Boiler Tube Co. of America, 3125 Preble Ave, N. S, Pittsburgh, Pa; h, R. D. 2, Coraopolis, Pa. .... **Linden 6350**

Boyd, W. Wallace (Nov. 1928) Chief Engineer, Standard Scale & Supply Company, Beaver Falls, Pa; h, 628 Beaver St, Sewickley, Pa,... .... **Beaver Falls 180**

Boyle, Walter William (May 1921) Supt. Buildings and Equipment, Joseph Horne Company; h, 512 McCully St, Mt. Lebanon, Pittsburgh, Pa.. **Court 3000**

Boyle, William George (May 1921) Engineer, Henry W. Oliver Estate, 423 Oliver Bldg, Pittsburgh, Pa; h, Bakerstown, Pa. . **Atlantic 0100**

Bracken, Michael Joseph (Feb. 1905) Pres, Argyle Coal Co, 606 First National Bank Bldg, Johnstown, Pa; h, 1071 McKinley Ave, Johnstown, Pa.

Braden, Earle Vance (June 1911) Engineer of Construction, Monongahela Railway Co, and Pittsburgh, Chartiers & Youghiogheny Rwy. Co, 1200 Century Bldg, Pittsburgh, Pa; h, 38 Steuben Ave, Crafton, Pittsburgh, Pa. . . . . **Atlantic 5244**

Bradford, H. H. (**Associate Member**) (Jan. 1923) Institutional Finance Director, Ketchum Inc, 2020 Koppers Bldg; h, 6 Highland Court, Pittsburgh, Pa. . . . . **Atlantic 1100**

Bradley, John Rodgers, (Oct. 1926) V. P, Duff Patents Co, Inc, 991 Union Trust Bldg, Pittsburgh; h, 114 Washington Ave, Bellevue, Pittsburgh, Pa. . . . . **Atlantic 5235**

★**Bradshaw, Grant D.** (July 1916) President, Bradshaw and Company, 530 Fourth Avenue, Pittsburgh, Pa; h, 186 Beaver St, Beaver, Pa. . . . . **Court 2627**

Brady, Hugh S. (Feb. 1928) Dist. Mgr, West Virginia, Hazel-Atlas Glass Co, Wheeling, W. Va.

Brahm, Harry Oliver (**Junior**) (Oct. 1925) Brahm & Worley, 902 House Bldg; h, 4918 Baum Blvd, Pittsburgh, Pa. . . . . **Court 0541**

★**Brandt, Edgar C.** (March 1917) Assistant Works Mgr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 1204 Milton Ave, Regent Square, Swissvale, Pittsburgh, Pa. . . . . **Brandywine 1500**

Branson, Craig Ridgway (May 1903) Mechanical Inspector, Pennsylvania Railroad, 500 Union Station, Chicago, Ill; h, 6039 Woodlawn Ave, Chicago, Ill.

Braun, William Paul (April 1928) Asst. Engr, Blum, Weldin & Co, 417 Grant St; h, 2929 Parkdale Ave, Carrick, Pittsburgh, Pa. . **Court 4997**

Bray, James M. (April 1911) Representative & Roll Designer, United Engrg. & Fdry. Co, Farmers Bank Bldg; h, 4373 Stanton Ave, Pittsburgh, Pa. . . . . **Atlantic 0863**

★**Bray, Thomas Joseph** (June 1902) h, 1510 5th Ave, Youngstown, O.

Breed, Charles Warren Jr. (**Junior**) (Oct. 1924) 1508 Center St, Wilkinsburg, Pittsburgh, Pa.

Breisky, John V. (**Associate Member**) (Sept. 1929) Section Engineer, Supply Eng. Dept, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 7505 Rosemary St, Pittsburgh, Pa. . **Brandywine 1500**

Bremmer, Floyd W. (**Junior**) (Feb. 1925) Hot Mill Foreman, Standard Seamless Tube Co, Ambridge, Pa. . . . . **Ambridge 380**

★**Brigel, Samuel G** (May 1902) h, 1127 N. Highland Ave, Pittsburgh, Pa.

Bright, Graham (Dec. 1923) Sales Engr, Mine Safety Appliances Co, Braddock Ave. & Thomas Blvd, Pittsburgh, Pa; h, 20 Bryn Mawr Road, Wilkinsburg, Pittsburgh, Pa. . . . . **Churchill 5900**

Brinker, Harry Louis (Oct. 1913) Works Supt, Brier Hill Works, Youngstown Sheet & Tube Co; h, 255 Arlington St, Youngstown, Ohio.

Britton, J. Robert (Student Junior) (Dec. 1928) Engineer, Duquesne Light Co, Duquesne Bldg, h, 4807 Baum Blvd, Pittsburgh, Pa. . . . . **Grant 4300-Ext. 530**

Broden, Edwin R. (Junior) (November 1929) Engineer in Power Dept. Division, American Sheet & Tin Plate Co, Room 1228, Frick Bldg; h, 132 Hawthorn St, Edgewood, Pittsburgh, Pa . . **Atlantic 1300**

Brooks, Joseph Bradford (Sept. 1918) Draftsman, Bureau of Bridges, Allegheny County, 519 Smithfield St; h, 424 Lloyd St, Homewood Station, Pittsburgh, Pa. **Atlantic 4900-Ext. 320**

Brosius, Edgar E. (Jan. 1912) President, Edgar E. Brosius, Inc, Sharpsburg, Pa; h, 6550 Beacon St, Pittsburgh, Pa. . . . . **Sterling 2086**

Brosius, William Orien (Dec. 1905) Mech. Engr, The Koppers Construction Co, Koppers Bldg; h, 1513 Hillsdale Ave, Dormont, Pittsburgh, Pa. . . . . **Atlantic 6240**

Brotzman, William S. (March 1926) Meteorologist, U. S. Weather Bureau, 2532 Oliver Bldg; h, 1641 Suburban Ave, Beechview, Pittsburgh, Pa. . . . . **Atlantic 1484**

Brown, Albert A. (Oct. 1926) Structural Engr, Jones & Laughlin Steel Corp, 3450 2nd Ave; h, 2329 Eldridge St, Squirrel Hill, Pittsburgh, Pa. . . . . **Atlantic 9670**

Brown, Charles F. (March 1923) Principal Asst. Engr, Bureau of Water, City of Pittsburgh, 531 City-County Bldg; h, 508 Rossmore Ave, Pittsburgh, Pa. . . . . **Atlantic 3900-Ext. 200**

Brown, Edwin Corner (Nov. 1906) Chf. Civil Engr, Carnegie Steel Co, 1012 Carnegie Bldg; h, 210 Maple Ave, Edgewood, Pittsburgh, Pa. . . . . **Atlantic 5100**

Brown, Harry D. (June 1912) Draftsman, National Tube Co, McKeesport, Pa; h, 519 S. Lang Ave, Pittsburgh, Pa. . . . . **McKeesport 4144**

Brown, Herbert Vincent (Dec. 1928) General Manager, The Brown-Fayro Co, 940 Ash St, Johnstown, Pa; h, 623 Luzerne St, Johnstown, Pa.

Brown, James M. (Dec. 1927) Sales Engr, Surface Combustion Co, 966 Union Trust Bldg; h, 417 Jonathan Court, Homewood Sta, Pittsburgh, Pa. . . . . **Atlantic 2946**

Brown, John T. Jr. (June 1911) Supt, Duquesne Reduction Co, Gross & Yew Sts; h, 6667 Woodwell St, Pittsburgh, Pa. . . . . . . **Schenley 2410**

Brown, Norman Fred (Nov. 1903) Director, Dept. of Public Works, Allegheny County, 519 Smithfield St; h, 707 Amberson Ave, Pittsburgh, Pa. . . . . **Atlantic 4900-Ext. 240**

Brown, Samuel Byrne (Oct. 1924) c/o Ford, Bacon & Davis, 39 Broadway, New York, N. Y.

Brown, William Edward (Associate Member) (April 1926) Chief Engr, The Vang Construction Co, 3022 Grant Bldg; h, Cathedral Mansions, Pittsburgh, Pa.......................... **Grant 8520**

Bruner, Fred (Jan. 1916) Engr, Walter S. Rae, 439 Oliver Bldg; h, 4761 Liberty Ave, Pittsburgh, Pa...................... **Atlantic 0707**

Bruner, William J. (Jan. 1922) Asst. Engr, Heyl & Patterson, Inc, 49-53 Water St; h, 3254 Orleans St, Pittsburgh, Pa........... **Court 0753**

Bryan, Joseph (April 1925) Asst. Manager, General Electric Co, 1315 Oliver Bldg; h, 1147 Wightman St, Pittsburgh, Pa........... **Atlantic 6400**

Buchanan, Edward Roberts (Jan. 1925) Business for self, 610 Magee Bldg; h, 121 Lincoln Ave, Edgewood, Pittsburgh, Pa......... **Court 1381**

Buell, Frank T. (Nov. 1927) Senior Asst. Engr, Mechanical Division, Bureau of Water, City of Pittsburgh, 312 City-County Bldg; h, 211 Jucunda St, Mt. Oliver Sta, Pittsburgh, Pa.. **Atlantic 3900–Ext. 46**

★**Buell, William C., Jr.** (May 1920) c/o Arthur G. McKee Co, Cleveland, Ohio.

Buente, Charles F. (Jan. 1887; April 1916) Secy, Concrete ProductsCo. of America, Diamond Bank Bldg; h, 2721 Miles Ave, Dormont, Pittsburgh, Pa................................ **Atlantic 3841**

BUENTE, WILLARD HARRISON (Chairman Practicing Engineers' Section) (Oct. 1915) Prin. Asst. Engr, The W. G. Wilkins Co, 909 Westinghouse Bldg; h, 3525 Diploma St, N. S. Pittsburgh, Pa. **Atlantic 4141**

Buenting, Otto W. (Dec. 1927) Genl. Mgr. of Works, Union Switch & Signal Co, Swissvale, Pa; h, 512 East End Ave, Pittsburgh, Pa.. **Penhurst 0880**

Buerger, Charles B. (March 1927) Vice President, Gulf Refining Co, P. O. Box 1214, Frick Bldg. Annex; h, 120 Ruskin Ave, Pittsburgh, Pa.. **Atlantic 5300**

Buhl, William (Associate Member) (March 1927) Sales Engr, Dravo-Doyle Co, 300 Penn Ave; h, 1458 Grandin Ave, Dormont Pittsburgh, Pa... **Court 5400**

Bulmer, William Carr (Nov. 1928) Sales Engineer, Blaw-Knox Co, P. O Box 915, Pittsburgh, Pa; h, 419 Lexington Ave, Aspinwall, Pittsburgh, Pa................................ **Sterling 2700**

Burden, Howard Watrous (Junior) (Oct. 1925) Test Engr, Duquesne Light Co, 700 Duquesne Bldg; h, 4 Sherman St, Cheswick, Pa.. **Grant 4300-Ext. 492**

Burgess, Charles Calvin (March 1923) Oper. Mgr. & Consulting Engr, Duquesne Slag Products Co, 810 Diamond Bank Bldg; h, 6842 Thomas Blvd, Pittsburgh, Pa............... **Atlantic 3841-Ext. 283**

Burgess, Henry Russell (Junior) (Feb. 1927) Engr, H. H. Robertson Co Grant Bldg; h, 6842 Thomas Blvd, Pittsburgh, Pa... **Atlantic 3200**

Burgham, Maurice L. (Junior) (April 1927) Mech. Engr, Edgewater Steel Co, Pittsburgh, Pa; h, 440 Freeport St, Parnassus, Pa. **Oakmont 280**

Burns, Stewart H. (April 1921) Boro Engr, Millvale, Etna & Sharpsburg; h, 518 North Ave, Millvale, Pa.................... **Millvale 1185**

Burr, Robert B. (May 1913) Mgr, Industrial Gas Sales, Ohio Fuel Gas Co, 99 N. Front St; h, 103 Pacemont Rd, East, Columbus, O.

Burton, John Earl (Associate Member) (March 1928) Proprietor, Prosperity Sales Service Co, 112 Washington St; h, 1138 Brookline Blvd, Pittsburgh, Pa.................................. **Atlantic 0892**

Busch, Herman F. (April 1904) Supt, Armstrong Cork Co, 24th St. & A. V. R. R, Pittsburgh; h, 420 North Ave, Millvale, Pa.... **Atlantic 7474**

Bushnell, Carl D. (May 1921) Pres, The Bushnell Machinery Co, 1501 Grant Bldg, Pittsburgh, Pa; h, Rosslyn Farms, Carnegie Pa.. .... **Atlantic 0417**

Butler, A. G. (Nov. 1929) Mgr, Pittsburgh Branch, Byllesby Engineering & Management Corp, 435 Sixth Ave; h, 5511 Fair Oaks Street, E. E, Pittsburgh, Pa.............. **Grant 5750-Line 557**

★**Butl3r, Richard Ellis (Associate Member)** (April 1921) Dist. Sales Mgr, The Babcock & Wilcox Co, 2730 Koppers Bldg; h, 515 Amberson Ave, Pittsburgh, Pa......................... **Atlantic 0672**

Butler, Thomas Emmet (Oct. 1924) Sales Engr, Peoples Natural Gas Co, 545 William Penn Way; h, 645 Madison Ave, McKeesport, Pa. .... **Grant 5100**

Butt, Howard (Oct. 1920) Sales Mgr, Air Preheater Corp, 25 Broadway, New York; h, 34 Pondfield Road, W. Bronxville, N. Y.

Buxton, Jay James (Associate Member) (June 1923) Dist. Supt. of Erection, The Babcock & Wilcox Co, 2730 Koppers Bldg; h, 65 Craighead St, Pittsburgh, Pa................................ **Atlantic 0672**

Buys, Orville (Associate) (Dec. 1928) Pres, Buys Engineering Co, 62 Vandergrift Bldg, Pittsburgh, Pa; h, 32 Nickolson St, Crafton, Pittsburgh, Pa.................................. **Court 1620**

Byrne, William Luke, (Nov. 1929) Air Engineering Equipment, 4 Smithfield Street; h, 5169 Woodworth Street, Pittsburgh, Pa.. **Court 5697**

Byrnes, Charles J. (Sept. 1917) Structural Steel Designer, The Koppers Construction Co, Koppers Bldg; h, 7120 Mt. Vernon St, Pittsburgh, Pa....................................... **Atlantic 6240**

Cadman, Alexander M. (Jan. 1925) Secy. & Treas, A. W. Cadman Mfg. Co, 2814-16 Smallman St, Pittsburgh, Pa; h, 349 Maple Ave, Edgewood, Pittsburgh, Pa................................ **Atlantic 6683**

Cadmann, M. McW. (Jan. 1903) Chemist, Carnegie Steel Co, 821 Carnegie Bldg, Pittsburgh, Pa; h, Edgewood, Pittsburgh, Pa.. **Atlantic 5100**

Caffal, Geoffrey Arthur (Feb. 1927) Mgr. of Erection, McClintic-Marshall Co, 1324 Oliver Bldg; h, King Edward Apts, Pittsburgh, Pa.. **Atlantic 2562**

Caldwell, Paul (Nov. 1923) Sales Engr, General Electric Co, 1314 Oliver Bldg; h, 600 Gettysburg St, Pittsburgh, Pa.......... **Atlantic 6400**

Callery, James D. (Feb. 1916) Pres, Diamond National Bank, Fifth and Liberty Aves; h, 718 Devonshire St, Pittsburgh, Pa.. **Atlantic 3475**

Cameron, Harry E. (**Associate Member**) (April 1928) Designing Engr, American Bridge Co, 1420 Frick Bldg; h, 1253 Tennessee Ave, Dormont, Pittsburgh, Pa.......................... **Atlantic 4300**

Campbell, J. R. (May 1928) Bituminous Rep, Koppers-Rheolaveur Company, Box 486, Scottdale, Pa; h, 1111 Loucks Ave, Scottdale, Pa. .... **Scottdale 55**

Campbell, John T. (March 1923) Member of Firm, The J. N. Chester Engineers, 813 Clark Bldg; h, 6627 Church Ave, Ben Avon, Pittsburgh, Pa.................................... **Atlantic 1140**

Campbell, R. D. (Sept. 1924) V. P, Allegheny Steel Co, Brackenridge, Pa; h, 1345 Inverness Ave, Pittsburgh, Pa................ **Grant 2766**

Canan, W. D. (**Associate Member**) (Oct. 1925) Mech. Engr, Rust Engineering Co, Koppers Bldg, Pittsburgh, Pa; h, 1215 Walnut St, Wilkinsburg, Pittsburgh, Pa............................. **Atlantic 8870**

Candy, A. M. (Dec. 1928) General Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 1108 Sherman St, Wilkinsburg, Pittsburgh, Pa.................................. **Brandywine 1500**

Cappeau, Jo P. (**Associate Member**) (Jan. 1925) Room 1041 Kennedy Bldg, Tulsa, Okla; h, Water Mill, L. I, N. Y.

Carlock, John Bruce (Oct. 1928) Chief Engineer, Jones and Laughlin Steel Corp, 27th and Carson Sts, South Side, Pittsburgh, Pa; h, 5429 Bartlett Street, Pittsburgh, Pa.................. **Hemlock 0401**

Carlson, Clifford E. (**Junior**) (Dec. 1928) Asst. Supt, National Valve & Mfg. Co, Liberty Ave; h, 903 Bryn Mawr Road, Pittsburgh, Pa. .... **Atlantic 6730**

Carlson, Earle Charles (**Junior**) (March 1927) Draftsman, The Rust Engineering Co, Koppers Bldg; h, 4221 Windsor St, Squirrel Hill P. O, Pittsburgh, Pa................................ **Atlantic 8870**

Carnes, William K. (Oct. 1911; Feb. 1926) Asst. Chf. Engr, Schoen Works, Carnegie Steel Co, McKees Rocks, Pa; h, 23 Emerson Ave, Crafton, Pittsburgh, Pa................................. **Federal 1061**

★**Carpenter, Charles A.** (March 1922) Mfgrs. Rep, Park Bldg; h, 5634 Hampton St, Pittsburgh, Pa.................... **Atlantic 1488**

Carr, John Crozier (Dec. 1905) Employment Superintendent, Jones & Laughlin Steel Corp, S. 27th & Carson Sts, Pittsburgh, Pa; h, 56 Parke St, Crafton, Pittsburgh, Pa................ **Hemlock 0401**

Carr, Uhel U. (Jan. 1925) V. P. & Gen. Mgr, Diamond Machine Co, P. O. Box No. 411; h, 900 Sheridan St, Monongahela, Pa... **Monongahela 9**

Carten, Charles N. (Feb. 1912) Senior Asst. Engr, Bureau of Water, City of Pittsburgh, City-County Bldg; h, 400 S. Linden Ave, Pittsburgh, Pa.......... **Atlantic 3900**

Carter, Edgar Levis (**Associate Member**) (Oct. 1928) Chief Clerk, Robinson, Butler, Hemingway & Co, Inc, Clairton, Pa; h, 215 N. Craig St, Pittsburgh, Pa.

Cary, Emmet Foster (March 1929) Manager, Coupling Dept, The Bartlett Hayward Co, Baltimore, Md; h, Chelsea Terrace, Baltimore, Md.

Casey, John F. (March 1924) Pres, John F. Casey Co, Box 1753, Pittsburgh; h, 4789 Wallingford St, Pittsburgh, Pa....... **Sterling 1400**

Chalfant, Frederick Bernard (Nov. 1913) Div. Engr, Div. of Surveys, City of Pittsburgh, City-County Bldg; h, 5558 Avondale Place, Pittsburgh, Pa.......... **Atlantic 3900**

Chandler, R. W. (Dec. 1927) 356 Franklin St, Worcester, Mass.

CHANDLER, WILLARD P. Jr. (**Chairman Mechanical Section**) (June 1914; Feb. 1918) Chief Engr, Furnace Div, Blaw-Knox Co, P. O. Box 915, Pittsburgh; h, 426 S. Linden Ave, Pittsburgh, Pa.......... **Sterling 2700**

Chaney, George Scott (April 1925) County Engr, Washington County, Court House, Washington, Pa; h, 549 E. Chestnut St, Washington, Pa.

Chapman, William B. (June 1922) Pres, Chapman Engineering Co, 50 Church St, New York, N. Y; h, 155-24th St, Jackson Heights, Long Island, N. Y.

Chappell, Thomas V. (**Junior**) (Jan. 1923) Clerk, National Tube Co, 1618 Frick Bldg; h, 238 Gladstone Road, Squirrel Hill, Pittsburgh, Pa.......... **Atlantic 2500**

Charles, Howard B. (**Associate**) (April 1924) Secy. & Treas, Industrial Paint Co, 1444 Oliver Bldg, Pittsburgh, Pa; h, 522 Hill Ave, Wilkinsburg, Pittsburgh, Pa.......... **Atlantic 2954**

Chartener, Victor, Jr. (May 1925) Asst. Chief Engr, Pittsburgh Steel Co; h, 414 Park Way, Monessen, Pa.......... **Monessen 360**

Cherrington, George H. (Feb. 1913) Pres, Machinists Supply Co, and Brown & Zortman Machinery Co, 325 Blvd. of the Allies; h, 5851 Marlborough St, Pittsburgh, Pa.......... **Court 0890**

Chesrown, Elias (July 1912) Engr, Westinghouse Elec. & Mfg. Co, 1800 Grant Bldg; h, 1403 N. St. Clair St, Pittsburgh, Pa.. **Atlantic 8400**

★**CHESTER, JOHN NEEDELS** (**Past President 1929**) (Dec. 1896) Senior Partner, The J. N. Chester Engineers, 813 Clark Bldg, Pittsburgh, Pa.......... **Atlantic 1140**

Chester, Walter Durst (Sept. 1918) Asst. Designer, Jones & Laughlin Steel Corp, 3450 Second Avenue; h, 249 Paul St, Mt. Washington Sta, Pittsburgh, Pa.......... **Atlantic 9670**

★**Chester, Wilfred Dudley** (April 1900) Retired; h, 238 Thorn Street, Sewickley, Pa.

★**Chesterman, Francis John** (Jan. 1928) Vice Pres. & Genl. Mgr, The Bell Telephone Co. of Pa, 416 Seventh Ave; h, 205 Lytton Ave, Pittsburgh, Pa .... **Official 0050**

Chew, Robert E. (**Associate**) (May 1929) Vice Pres. and Genl. Mgr, Ladd Equipment Co, Farmers Bank Bldg; h, 265 Cochran Road, Mt. Lebanon, Pittsburgh, Pa .... **Atlantic 1984**

Chickering, Tileston (Feb. 1911) Estimator, Carnegie Steel Co, 427 Carnegie Bldg, Pittsburgh, Pa; h, 1445 Beaver Road, Glen Osborne, Sewickley, Pa .... **Atlantic 5100**

Childs, H. P. (**Associate**) (Dec. 1928) 420 Lexington Avenue, 29th floor, New York City.

Christianson, Andrew (**Associate Member**) (Nov. 1912) Chf. Engr, Standard Steel Car Co, Pittsburgh, Pa; h, Box 877, Butler, Pa... **Atlantic 1833**

Christie, Lindsay R. (Sept. 1928) President, L. R. Christie Company, Union Trust Building; h, 1608 Denniston Street; Pittsburgh, Pa. .... **Atlantic 5235**

Christy, George Lewis (Feb. 1915) Chief Engr, Pittsburgh-Des Moines Steel Co, Neville Island; h, 5586 Pocussett St, Pittsburgh, Pa... .... **Federal 3000**

Church, Walter S. (Dec. 1912) Asst. Supt. Bldg. & Mech, Dept, Byllesby Engineering & Management. Corp, 435 Sixth Ave; h, 6413 Jackson St, Pittsburgh, Pa .... **Grant 5750**

Clagett, Thomas H. (Nov. 1902; April 1916) Chief Engr, Pocahontas Coal & Coke Co, Box 617, Bluefield, W. Va.

Clark, Charles H. (May 1921) Pres, Clark Car Co, Hanna Bldg, Cleveland, Ohio; h, The Hedges, R. D. 1, Library, Pa.

Clark, Eben B. (May 1903) Vice Pres, Firth-Sterling Steel Co, Oliver Bldg; h, Morewood Gardens, Pittsburgh, Pa....... **Atlantic 0471**

Clark, Milnor P. (Feb. 1900) Mgr, E. I. Clark Hdw. Co, 1213 Fifth Ave; h, 1408 Bailey Ave, McKeesport, Pa .... **McKeesport 20957**

Clark, Donald G. (March 1928) Director of Sales, Firth Sterling Steel Co, McKeesport, Pa; h, 925 Amberson Ave, Pittsburgh, Pa........ .... **McKeesport 4181**

Clause, William L. (March 1921) Chairman Board of Directors, Pittsburgh Plate Glass Co, 2203 Grant Bldg, Pittsburgh, Pa; h, Creek Drive, Sewickley, Pa .... **Atlantic 5600**

Clement, Albert E. (**Associate Member**) (Dec. 1927) Engr, Natrona Light & Power Co, and Natrona Water Co; h, Fourth Ave. and Keystone St, Natrona, Pa .... **Tarentum 1507**

Clifford, Thomas C. (Feb. 1914) h, 7145 Thomas Blvd, Pittsburgh, Pa. .... **Hiland 8380**

Cline, John Russell (April 1920) Asst. Supt, Universal-Atlas Cement Co, Universal, Pa; h, 8920 Upland Terrace, Wilkinsburg, Pittsburgh, Pa .... **Unity 8**

Clyde, William Gray (March 1924) Pres, Carnegie Steel Co, 1116 Carnegie Bldg; h, 1515 Beechwood Blvd, Pittsburgh, Pa .... **Atlantic 5100**

Cochran, John S. (July 1910) Pres, Mac-It Parts Co; h, Lancaster, Pa.

Cogswell, Frederick R. (**Associate Member**) (May 1921) Director, Traffic Promotion, Pittsburgh Railways Co, 435-6th Ave; h, 5716 Solway St, Pittsburgh, Pa .... **Grant 7450-Ext. 149**

Cole, Henry Ernest (April 1910) Pres, Harris Pump & Supply Co, 320-2nd Ave; h, 6100 Stanton Ave, Pittsburgh, Pa .... **Court 3800**

Cole, Herbert F. (Nov. 1925) In Charge, Small Industrial Sales, General Electric Co, 1318 Oliver Bldg; h, 7114 Hermitage St, Pittsburgh, Pa .... **Atlantic 6400**

Coles, Henry Taunton (Feb. 1925) Engr, Hyde & Co. Inc, 323 Fourth Ave, Pittsburgh; h, 431 Beaver St, Beaver, Pa .... **Court 1329**

Colgan, Charles Judson (Dec. 1924) Research Engineer, Monongahela West Penn Public Service Co, Fairmont, W. Va.

Collord, George L. (May 1921) V. P., The Shenango Furnace Co, 812 Oliver Bldg, Box 1106, Pittsburgh; h, 808 Morewood Ave, Pittsburgh, Pa .... **Atlantic 0987**

Comstock, Glenn Moore (Nov. 1924) Sales Manager, Rush Machinery Co, 32 E. Carson St, Pittsburgh, Pa; h, 154 College Ave, Beaver, Pa. .... **Court 1520**

Comstock, Ralph A. (**Associate Member**) (June 1928) Sales and Service Engineer, W. H. Nicholson & Co, Wilkes-Barre, Pa; h 309 W. Otterman St, Greensburg, Pa.

Connar, V. N. (March 1929) Eastern Manager, Service Bureau, Universal Atlas Cement Co, 516 Frick Bldg; h, 9 Hawthorne Ave, Crafton, Pittsburgh, Pa .... **Atlantic 2087**

Connell, Howard R. (Dec. 1924) General Electric Co, Box 535, Brackenridge, Pa; h, 1108 Park St, Tarentum, Pa .... **Tarentum 1000**

Connelley, Clifford Brown (May 1891) Secy-Treas, Marine Mfg. & Supply Co, 35 Water St; h, 300 Marsonia Ave, N. S, Pittsburgh, Pa .... **Court 4200**

Connor, Francis A. (Nov. 1927) Sales Engineer, General Electric Co, 1318 Oliver Bldg; h, 34 Academy Ave, So. Hills Sta, Pittsburgh, Pa .... **Atlantic 6400**

Cook, Charles C. (March 1917) Maintenance Engr, Baltimore & Ohio R. R. Co, 1201 Baltimore & Ohio Bldg; h, 3537 Liberty Heights Ave, Baltimore, Md.

Cook, John Orth (Associate Member) (Oct. 1929) Draftsman, Allegheny County Dept. of Public Works, Room 102, 519 Smithfield St; h, 544 Rossmore Avenue, South Hills Branch, Pittsburgh, Pa. .... **Atlantic 4900-Line 156**

Cooke, M. W. (Dec. 1926) Superintendent of Traffic Pittsburgh Railways Co, 435-6th Ave; h, 221 Parker Drive, Mt. Lebanon, Pittsburgh, Pa.......... **Grant 7450-Ext. 162**

Cooley, Herbert M. (Nov. 1918) Asst. Chief Inspector, National Tube Co McKeesport, Pa; h, 1011 Park St, McKeesport, Pa.......... **McKeesport 4144**

Coolidge, G. Greer (Jan. 1912) Asst. Gen. Sales Mgr, Harbison-Walker Refractories Co, Farmers Bank Bldg; h, 5440 Aylesboro Ave, Pittsburgh, Pa.......... **Atlantic 0942**

Cooper, Frederick M. (April 1921) Civil Engr, Edeburn Cooper Co, Law and Finance Bldg; 429 Fourth Ave, Pittsburgh, Pa; h, Rose St, Coraopolis, Pa.......... **Atlantic 0898**

Cooper, Howell C. (Jan. 1923) Vice Pres. and Chief Engr, Hope Natural Gas Co, 545 William Penn Way; h, 232 Little St, Sewickley, Pa. .... **Grant 5100**

Cooper, Leroy Warrick (May 1927) Gen. Supt. Mines, West Penn Power Co, 14 Wood St, Pittsburgh; h, 1208 LaClair Ave, Swissvale, Pittsburgh, Pa.......... **Court 4106**

Cooper, Maurice Diehl (Oct. 1916; Oct. 1926) Asst. Gen. Supt, Hillman Coal & Coke Co, 2304 First National Bank Bldg; h, 5430 Aylesboro Ave, Pittsburgh, Pa.......... **Atlantic 2620**

Corey, William Ellis (May 1897), Director, Bethlehem Steel Corp, 25 Broadway; h, 991 Fifth Ave, New York, N. Y.

Cornelius, Henry R. (Dec. 1911) Sales Engr, Mesta Machine Co, 1943 Oliver Bldg, Pittsburgh, Pa; h, R. D. No. 1, Coraopolis, Pa.......... **Atlantic 1472**

Cornelius, William A. (Nov. 1899; Dec. 1920) Retired; h. Emlen Arms, Emlen St., Germantown, Philadelphia, Pa.

Coryell, William Clayton (Nov. 1914) Consulting Engr, Specializing in cold rolling or strip metal and continuous sheets. Also steel lath-making machinery; h, 1719 Ohio Ave, Youngstown, O.

Cosgrove, William H. (Nov. 1922) Treasurer, Wm. Swindell & Bros, P. O. Box 1753, Pittsburgh; h, 5712 Howe St, Pittsburgh, Pa. .... **Sterling 1400**

Coslow, Carl W. (Dec. 1928) Supt. The Selden Co, Macartney St, W. E; h, 5854 Alderson St, Pittsburgh, Pa.......... **Walnut 1900**

Cott, Parker (April 1925) Field Representative, American Mining Congress Journal, Washington, D. C, also Mgr. Pittsburgh Branch, Scranton Pump Co, 406 Empire Bldg; h, 6345 Glenview Place, Pittsburgh, Pa..**Atlantic 6348**

Cotter, George L. (Associate Member) (Jan. 1925) District Engr, Westinghouse Air Brake Co; h, 353 Marguerite Ave, Wilmerding, Pa...**Brandywine 1490-Ext. 311**

★**Covell, Vernon Royce** (Nov. 1897) Chief Engr, Bureau of Bridges, Dept. Public Works, Allegheny Co, 519 Smithfield St, Pittsburgh; h, 816 South Ave, Wilkinsburg, Pittsburgh, Pa...**Atlantic 4900-Ext. 202**

Cowin, Stuart H. (Associate Member) (Dec. 1928) Engr, Railway Motor Dept, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, c/o Clover Club, 6744 Penn Ave, Pittsburgh, Pa....**Brandywine 1500**

Coxe, Edward Haviland (Jan. 1917) 25 Second National Bank Bldg; h, 30 Oakland Ave, Uniontown, Pa...............**Uniontown 3132**

Crafton, H. Herbert (Associate Member) (Dec. 1927) Works Engr, H. H. Robertson Co, Ambridge, Pa; h, Box 131, Baden, Pa.

Craig, Albert Burchfield (Feb. 1925) General Manager, Chartiers Oil Co, 808 Columbia Bank Bldg, Pittsburgh, Pa; h, 234 Graham St, Sewickley, Pa..................................**Court 3404**

Cramer, Robert Edward (Oct. 1923) District Engineer, American Steel & Wire Co, 830 Frick Bldg, Pittsburgh, Pa; h, 102 Catskill Ave, Brentwood Boro, Pittsburgh, Pa........................**Atlantic 5720**

Crane, J. B. (June 1921) District Mgr, Combustion Engr. Corp, 1606 First National Bank Bldg, Pittsburgh, Pa............**Atlantic 1511**

Crawbuck, John D. (Associate Member) (June 1927) Proprietor, John D. Crawbuck Co, 406 Empire Bldg; h, 1440 Severn St, Pittsburgh, Pa..**Atlantic 6348**

Crawford, David Francis (June 1899) Consulting Engr; h, 5243 Ellsworth Ave, Pittsburgh, Pa..........................**Mayflower 4360**

Crawford, Loyal F. (May 1914; Feb. 1924) Partner, Coal Mine Equipment Co, 2218 Farmers Bank Bldg, Pittsburgh, Pa.........**Atlantic 2700**

Crawford, Robert M. (Sept. 1927) Chemical & Industrial Engr, Private Practice, 48 Hyman Blvd, Buffalo, N. Y.

Crellin, Edward W. (May 1919) Engineer, 1559 San Pasqual St, Pasadena, Calif.

Criswell, John Russel (Sept. 1929) Treasurer, James Criswell Co, 1204 Keenan Bldg; h, 59 N. Fremont St, Bellevue, Pittsburgh, Pa. ....**Atlantic 5428**

Critchlow, Paul N. (March 1920) Patent Attorney, Brown & Critchlow, 1521 Farmers Bank Bldg, Pittsburgh, Pa; h, 618 Harbaugh St, Sewickley, Pa....................................**Atlantic 2271**

Croak, John J. (Sept. 1922) Div. Engr, Division of Design, Bureau of Engineering, City of Pittsburgh, 442 City-County Bldg; h, 2636 Pioneer Ave, Pittsburgh, Pa........................**Atlantic 3900**

Crocker, Edward E. (Dec. 1904) Retired; h, Grandview Ave, Crafton, Pittsburgh, Pa.................................**Walnut 0231**

★**CROCKETT, ARTHUR E.** (**Silver Medal 1919**) (March 1909) Mgr. Bureau of Instruction, Jones & Laughlin Steel Corp, 311 Ross St; h, 120 Ruskin Ave, Pittsburgh, Pa.........................**Court 3240**

★**Crolius, Frederick Joseph** (June 1920) General Engr, Centrifix Corporation, 3029 Prospect Ave, Cleveland, O; h, 323 Lincoln Ave, Bellevue, Pittsburgh, Pa.

Cronemeyer, Henry C. (May 1903) Designer, Jones & Laughlin Steel Corp, Aliquippa, Pa; h, 181 College Ave, Beaver, Pa.......**Aliquippa 101**

Crooker, Ralph (March 1896) Acton, Mass.

Crouse, John L. (June 1918) Asst. to Transportation Sales Mgr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 401 S. Braddock Ave, Pittsburgh, Pa...........................**Brandywine 1500**

Culbertson, Albert Lewis (Oct. 1924) Mgr. Furnace Dept, The Rust Eng. Co, Koppers Bldg; h, 397 Jefferson Drive, Mt. Lebanon, Pittsburgh, Pa...**Atlantic 8870**

Culler, A. A. (April 1923) Partner, C. N. Haggart and A. A. Culler, 524 State Theatre Bldg, 335 Fifth Ave, Pittsburgh, Pa; h, 48 Highland Ave, Emsworth, Pa.............................**Atlantic 5349**

★**Cummings, Robert A.** (Feb. 1903) Consulting Civil Engineer, 311 Ross St; h, 5911 Elgin Ave, E. E. Pittsburgh, Pa...............**Court 2941**

Cummins, Alden Curry (March 1912) Supt, Electrical Dept, Carnegie Steel Co; h, 724 S. Duquesne Ave, Duquesne, Pa........ **Duquesne 5153**

Cundy, Oscar R. (**Associate Member**) (March 1916) Sales Engr, Sullivan Machinery Co, 518 Farmers Bank Bldg; h, 110 Marlin Drive, East, Mt. Lebanon, Pittsburgh, Pa.......................**Atlantic 2792**

Cunningham, David S. (**Junior**) (Jan. 1929) Draftsman, D. P. W, Bureau of Bridges, Div. of Design, Allegheny Co; h, 336 Breading Ave, Ben Avon, Pittsburgh, Pa...............**Atlantic 4900-Line 44**

Curtin, Joseph McMeen (June 1929) Industrial Sales Mgr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 1515 Whitman St, Pittsburgh, Pa..........................**Brandywine 1500**

Cutler, Day Emerson (Feb. 1926) Compressor Specialist, General Electric Co, 1317 Oliver Bldg; h, 1520 S. Negley Ave, Pittsburgh, Pa..... ....**Atlantic 6400**

Dake, Virgil H. (Feb. 1927) Supt. of Telephones, Philadelphia Co. and Affiliated Corps, 435-6th Ave; h, 931 Brookline Blvd, S. H, Pittsburgh, Pa.......................................**Grant 3200**

Dake, Walter M. (May 1926) Consulting Engr, in charge of Sales, Joy Mfg. Co, 505 15th St, Franklin, Pa.............. **Franklin 306-7**

Dalbey, J. L. (March 1929) Engineer, Jones & Laughlin Steel Corp, Aliquippa, Pa; h, 559 Twelfth Ave, New Brighton, Pa... **Aliquippa 101**

Dalzell, C. W. (**Associate**) (April 1928) Engr, Union Switch & Signal Co; h, 1015 S. Braddock Ave, Swissvale, Pittsburgh, Pa.. **Penhurst 0880-Line 296**

Damrau, Edward A. (**Associate**) (Feb. 1925) Dist. Mgr, The Okonite Co. and The Okonite-Callender Cable Co, 1111 First National Bank Bldg; h, 1306 Milton Ave, Regent Square, Pittsburgh, Pa.. **Atlantic 1761**

Danahy, John (**Associate Member**) (Dec. 1928) Treas. and Genl. Mgr. Penn-Pitt Coal & Coke Co, Greensboro, Greene County. Pa.

Dandridge, Edmund Pendleton (May 1919) Dist. Mgr, Stephens-Adamson Mfg. Co, 1624 Oliver Bldg; h, 1326 Sheridan St, Pittsburgh, Pa. .... **Atlantic 0490**

★**DANFORTH, GEORGE HAGAR** (**Past President 1921**) (Jan. 1904) Contracting Engr, Jones & Laughlin Steel Corp, 3rd Ave. & Ross St; h, 4800 Ellsworth Ave, Pittsburgh, Pa................ **Court 3240**

Daniel, Thomas Lester (March 1924) Machinery Development Engr, Seiberling Rubber Co, Akron, O; h, 4637 Aldrich Ave, Minneapolis, Minn.

Daniels, Q. C. (April 1904) Mechanical Engineer; h, 269 Main St, East Aurora, N. Y.

Dann, Alex. W. (**Associate Member**) (May 1921) V. P. & Gen. Mgr, Keystone Sand & Supply Co, Dravo Bldg, 300 Penn Ave, Pittsburgh, Pa; h, 1207-A Besner Rd, Glen Osborne, Sewickley, Pa.. .... **Court 5400**

Daryman, Thomas A. (Jan. 1925) Salesman, Ingersoll Rand Co, 706 Chamber of Commerce Bldg, Pittsburgh, Pa; h, 106 Cleveland Ave, Avalon, Pittsburgh, Pa.................................. **Atlantic 9070**

Daubert, Charles W. (March 1921) Engineering Dept, American Sheet & Tin Plate Co, 1228 Frick Bldg; h, 407 Oakland Ave, Pittsburgh, Pa. .... **Atlantic 1300**

Daum, Adam Edward (June 1904) President, Impervious Varnish Co, Koppers Bldg; h, 3238 Gaylord Ave, Dormont, Pittsburgh, Pa.... .... **Atlantic 0215**

Davies, John W. (April 1923) T. C. Allison Co, 812 Federal St, N. S; h, 1473 Alabama Ave, Dormont, Pittsburgh, Pa...... **Fairfax 0685**

Davies, Thomas P. (Nov. 1904) Chief Mech. Engr, Carnegie Steel Co, Duquesne Works; h, 913 Kennedy Ave, Duquesne, Pa......... .... **Duquesne 5153**

★**Davis, Charles Stratton** (May 1921) Consulting Engr, 903 Fulton Bldg, Pittsburgh, Pa; h, 306 Broad St, Sewickley, Pa..... **Atlantic 5923**

Davis, Clyde Ellsworth (Dec. 1923) 3705 Main St, Homestead Park, Homestead, Pa.

Davis, Daniel E. (March 1923) Member of Firm, J. N. Chester Engineers, 813 Clark Bldg, Pittsburgh, Pa; h, 214 Walnut St, Sewickley, Pa. .... **Atlantic 1140**

Davis, Harry Phillips (Dec. 1898; June 1924) V. P, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 4917 Wallingford St, Pittsburgh, Pa.. **Brandywine 1500**

Davis, Jefferson (Dec. 1924) Dist. Engr, Detroit Graphite Co, 947 Oliver Bldg; h, Keystone Athletic Club, Pittsburgh, Pa...... **Atlantic 4330**

Davis, Paul G. (**Associate**) (Feb. 1926) Sales Engr. & Dist. Mgr, Jennison-Wright Co. of Toledo, O, 604 Chamber of Commerce Bldg, Pittsburgh; h, 241 Dixon Ave, Ben Avon, Pittsburgh, Pa... **Atlantic 8741**

Davis, Ralph Emerson (March 1926) Consulting Engineer, 1710 Union Bank Bldg; h, 5614 Northumberland St, Pittsburgh, Pa... **Court 1776**

Davis, William Arthur (Jan. 1915) M. E, M. W. Kellogg Co, 225 Broadway, New York, N. Y; h, 23 Harvard St, East Orange, N. J.

DAVISON, ALLEN STEWART (**Director**) (June 1911) Vice Pres. and Treas, Davison Coke & Iron Co, 2119 Oliver Bldg; h, 210 Hawthorne St, Edgewood, Pittsburgh, Pa..................... **Atlantic 2290**

★**DAVISON, GEORGE S.** (**Past President 1898**) (Dec. 1880) Pres, Davison Coke & Iron Co. 2119 Oliver Bldg; h, Pittsburgh Athletic Association, Fifth Ave, Pittsburgh, Pa......................... **Atlantic 2290**

Deckman, Edward J. (Dec. 1910) Pres, E. J. Deckman Co, Sales Engineers, 902 Oliver Bldg; h, 5671 Beacon St, Pittsburgh, Pa..... **Atlantic 1843**

deFries, Walter (April 1924) Chf. Engr, Wm. B. Pollock Co, E. Federal St, Youngstown, O; h, 4302 Chester Drive, Newport Village, O.

Deike, George Herman (Dec. 1924) Pres. & Treas, Mine Safety Appliances Co, Braddock Ave. & Thomas Blvd; h, 1028 Sheridan Ave, Pittsburgh, Pa................................... **Churchill 5900**

Demorest, George Myron (**Associate Member**) (Jan. 1925) Dist. Repr, Irving Iron Works Co, 241 Union Trust Bldg; h, Schenley Arms Apts, Bigelow Blvd. & Center Ave, Pittsburgh, Pa......... **Atlantic 6238**

Dempler, George P. (April 1920) Pres, Geo. P. Dempler Co, 1206 House Bldg; h, 3318 Latonia Ave, Dormont, Pittsburgh, Pa... **Court 0610**

Denigan, Edward P. (**Associate Member**) (March 1927) Salesman, Pittsburgh-Des Moines Steel Co, Neville Island; h, Lebanon Hall, Mt. Lebanon, Pittsburgh, Pa............................ **Federal 3000**

Denison, Percy N. (**Associate**) (April 1929) Manager, E. I. DuPont DeNemours & Co, 1912 Clark Bldg, Pittsburgh, Pa; h, 624 Hamilton Road, Thornburg, Pittsburgh, Pa............**Atlantic 7777**

Dent, John Adlum (Nov. 1928) Professor of Mechanical Engineering, University f Pittsburgh, 102 Thaw Hall; h, 322 McKee Place, Pittsburgh, Pa................................**Mayflower 3500**

Desch, John Leo (Feb. 1927) 4 Commonwealth Ave, Boston, Mass.

Dethloff, William Louis (Nov. 1923) Pres. & Gen. Mgr, American Nickel Corp, Hyde, Clearfield Co, Pa; h, 122 Weaver St, Clearfield, Pa.

Deuel, Harry Austin (Dec. 1928) Chief Industrial Engr, Jones & Laughlin Steel Corp, S. S. Works; h, Schenley Apts, Pittsburgh, Pa..**Hemlock 0401**

de Vou, James L. (May 1921) Mgr, Central District, Erecting Dept, American Bridge Co, 1525 Frick Bldg; h, 5475 Bartlett St, Pittsburgh, Pa.....................................**Atlantic 4300**

Dibble, Robert Horace (May 1926) Metallurgical Engr, American Sheet & Tin Plate Co, 1302 Frick Bldg, Box 62, Pittsburgh; h, 423 Biddle Ave, Wilkinsburg, Pittsburgh, Pa..................**Atlantic 1300**

Dickerson, James Howard (Sept. 1910) Box 464, Welch, W. Va.

★**Diehl, Ambrose Nevin** (June 1901) V. P, Carnegie Steel Co, 1216 Carnegie Bldg; h, 5400 Hobart St, Pittsburgh, Pa..............**Atlantic 5100**

Diehl, David H. (Dec. 1925) Construction Supt, James L. Stuart, 518 Oliver Bldg; h, 909 Bayridge Ave, Pittsburgh, Pa....**Atlantic 0653**

★**Diescher, Alfred J.** (Sept. 1902) Pres, Emerald Oil Co, State Bank Bldg; h, Lagonda Hotel, Winfield, Kansas.

Diescher, Samuel Endres (Feb. 1903) Member of Firm, S. Diescher & Sons, Farmers Bank Bldg; h, 724 S. Negley Ave, Pittsburgh, Pa. ....**Atlantic 4975**

★**Dignan, George Edward** (April 1921) Chief Engr, Davison Coke & Iron Co, Neville Island, Pittsburgh, Pa; h, 26 Terrace Road, Rosslyn Farms, Carnegie, Pa.............................**Federal 3700**

Dilley, James Max (April 1924) Pgh. Repr, Bessemer Cement Corp, 925 Frick Bldg, Pittsburgh; h, 320 Frederick Ave, Sewickley, Pa...**Atlantic 0610**

Dillon, Sydney (March 1917) Chief Mechanical Engr, Carnegie Steel Co, 1216 Carnegie Bldg, Pittsburgh, Pa........**Atlantic 5100-Ext. 241**

Dinkey, Alva Clymer (Nov. 1897) Pres, The Midvale Co, Nicetown, Philadelphia, Pa; h, 314 Kent Road, Wynnewood, Pa.

DInneen, William Thomas (**Associate Member**) (Oct. 1926) Pres. & Treas, William T. Dinneen Construction Co, 23 Central Ave, Lynn, Mass; h, 20 Buchannan Circle, Lynn, Mass.

Dixon, Henry L. (Feb. 1905) President, H. L. Dixon Company, Rosslyn Road, Carnegie, Pa, Box 140, Pittsburgh, Pa; h, 2981 Voelkel Ave, Dormont, Pittsburgh, Pa.......................**Walnut 0403**

Dodworth, James Russell, Jr. (May 1926) Engr, Pittsburgh-Hanover Coal Co, Benedum Trees Bldg; h. 932 W. North Ave, N. S, Pittsburgh, Pa...**Court 4453**

Dolan, Albert Vincent (Nov. 1915) Engr, Erection Dept, Fort Pitt Bridge Works, 2026 Oliver Bldg, Pittsburgh; h, 107 Steuben St, Crafton, Pittsburgh, Pa..................................**Atlantic 0654**

Donahey, John Wellington (**Associate**) (Dec. 1929) Manager, Bettis Airport, Aircraft and Airways of America, Inc, P. O. Box 1126; h, 5562 Hobart St, Pittsburgh, Pa.......................**Homestead 3480**

Donald, John S. (**Junior**) (June 1925) Sales Engr, Blaw Knox Co, P. O. Box 915, Pittsburgh, Pa; h, 405 Hastings St., Pittsburgh, Pa...
....**Sterling 2700**

Donaldson, Joseph T. (Oct. 1903) Engr, Riter-Conley Works of the McClintic-Marshall Co, Pittsburgh, Pa; h, 148 Irwin Ave, Ben Avon, Pittsburgh, Pa..................................**Atlantic 2562**

Donaldson, Robert R., Jr. (Sept. 1921) Chief Engr, Service Dept, Hagan Corp, Bowman Bldg, Pittsburgh, Pa; h, 443 Cascade Rd, Forest Hills, Wilkinsburg, Pittsburgh, Pa...................**Court 4724**

Donnan, David M. (Sept. 1921) Pres. & Gen. Mgr, Electrical Engrg. & Mfg. Co, 907 Penn Ave; h, 49 Briar Cliff Road, Ben Avon Heights, Pittsburgh, Pa...................................**Grant 6693**

Dornbush, Charles C. (April 1915) Sales Engr, Jones & Laughlin Steel Corp, Ross St; h, 551 Highland Place, Bellevue, Pittsburgh, Pa.**Court 3240**

Dorsey, Charles H. (May 1925) Treas, The R. G. Johnson Co, 1110 House Bldg, Pittsburgh, Pa; h, 36 Huffman Ave, Washington, Pa.**Court 3753**

Dougall, C. R. (**Junior**) (Oct. 1928) Draftsman, The John N. Chester Engineers, Clark Bldg; h, 745 Glenn Avenue, Wilkinsburg, Pittsburgh, Pa.....................................**Atlantic 1140**

Douglas, Henderson B. (May 1905) Efficiency Engr, Standard Steel Car Co, Frick Bldg; h, 5301 Ellsworth Ave, Pittsburgh, Pa..**Atlantic 1833**

Dowling, Eugene (June 1928) Industrial Sales Mgr, Johns-Manville Corp, 6300 Euclid Ave, Cleveland, O; h, 3327 Kenmore Rd, Cleveland, O.

Down, S. G. (March 1924) V. P, Westinghouse Air Brake Co, Wilmerding, Pa; h, 204 Hawthorne St, Edgewood, Swissvale P. O, Pa.......
....**Brandywine 1490**

Downer, Charles Boddie (**Associate**) (Dec. 1926) Engr. in Charge of Distribution of Specifications, West Penn Power Co, 14 Wood St; h, 2703 Norwood Ave, N. S, Pittsburgh, Pa.............**Court 4106**

★**Drake, Chester Francis** (Dec. 1904) Supt. Filtration Div, Bureau of Water, City of Pittsburgh, Filtration Plant, Aspinwall Pittsburgh, Pa. . . . . **Sterling 0147**

★**Dravo, Francis Rouand** (Dec. 1904) Pres, Dravo Contracting Co, Dravo Bldg, 302 Penn Ave, Pittsburgh, Pa; h, East Drive, Sewickley, Pa. . . . . **Federal 2600**

Drylie, William A. (April 1925) Supt. Steam Dept, Edgar Thomson Works, Carnegie Steel Co, Braddock, Pa; h, 7316 Schoyer Ave, Swissvale, Pittsburgh, Pa. . . . . **Brandywine 2590-Ext. 23**

★**Duckham, Albert Edward** (March 1892) Consulting Civil Engr, 64 Vandergrift Bldg; h, 246 S. Aiken Ave, Pittsburgh, Pa. . . . . . . **Court 1926**

★**Duckworth, Thomas** (Feb. 1910) Erection Engr. & Supt, Honolulu Iron Wks. Co, United Sugar Companies of Mexico, Los Mochis, Sinaloa, Mexico; h, Birch & Railroad Aves, Hempstead, New York, N. Y.

Duden, Emil Gustav (April 1913) Chf. Engr, Water Purifying Dept, Wm. B. Scaife & Sons Co; h, Fourth St, Oakmont, Pa. . . . . **Oakmont 9**

Duff, J. Milton (May 1928) Consulting Engr, Phillips Mine & Mill Supply Co, 2227 Jane St; h, 211 The Boulevard, Mt. Oliver Station, Pittsburgh, Pa. . . . . **Hemlock 0130**

Duff, Levi Bird (Oct. 1913) Consulting Engr, Samuel E. Duff-Levi Bird Duff, Consulting Engrs, 712 Magee Bldg, Pittsburgh, Pa; h, 225 Dickson Ave, Ben Avon, Pittsburgh, Pa. . . . . **Court 3542**

★**DUFF, SAMUEL ECKERBERGER** (**Past President 1916**) (Oct. 1908) Consulting Engineer, Samuel E. Duff-Levi Bird Duff, Consulting Engineers, 712 Magee Bldg, Pittsburgh, Pa; h, 7177 Brighton Road, Ben Avon, Pittsburgh,Pa. . . . . **Court 3542**

Dunbar, Frank B. (Oct. 1927) Gen. Supt. Mather Collieries, Pickands, Mather & Co, Mather, Greene County, Pa.

Duncan, J. McA (March 1924) Asst. Genl. Sales Mgr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 340 S. Highland Ave, Pittsburgh, Pa. . . . . **Brandywine 1500**

Dunham, Byron W. (June 1921) Chief Engr, Edgewater Steel Co, Box 249; h, 434-9th St, Oakmont, Pa. . . . . **Oakmont 280**

Dunn, H. Earl (Dec. 1924) Metallurgical Asst. to V. P, Vanadium Corp. of America, Bridgeville, Pa; h, 19 N. Emily St, Crafton Sta, Pittsburgh, Pa. . . . . **Carnegie 1186**

Dunn, J. Jay (Feb. 1917) Genl. Supt, National Tube Co, Ellwood City, Pa.

Dunnels, Clifford George (March 1922) Member of Firm, Hunting, Davis and Dunnells, 1150 Century Bldg; h, 141 Riverview Ave, N. S, Pittsburgh, Pa. . . . . **Atlantic 6941**

Dunsford, Jan Rubidge (Nov. 1916) President, Union Steel Casting Co, 62nd and Butler Sts; h, 310 Quaker Road, Edgeworth, Pa. . . . . **Fisk 0456**

Dwelle, Edwin R. (**Associate Member**) (March 1929) Salesman Crane and Hoist Dept, Barney Machinery Co, 2410 Koppers Bldg, Pittsburgh, Pa; h, 123 Montclair Ave, West View, Pa... **Atlantic 4116**

Dyche, Howard Edward (Sept. 1926) Professor & Head, Dept. Electrical Engineering, University of Pittsburgh; h, 317 South Ave, Wilkinsburg, Pittsburgh, Pa.......... **Mayflower 3500**

Dykeman, Howard E. (Oct. 1927) Designing Engr, Consolidation Coal Co, Fairmont, W. Va; h, Box 308, Bell Run, Fairmont, W. Va.

Dym, Emanuel (**Associate**) (May 1924) Pres, Pittsburgh State Bank, 507 5th Ave; h, 5415 Hobart St, Pittsburgh, Pa.......... **Atlantic 8686**

Eastman, Horace Merriam (June 1911) Sales Engr, Jones & Laughlin Steel Corp, 165 Broadway, New York, N. Y; h, 56 S. Walnut St, East Orange, N. J.

Eastwood, Sidney K. (May 1921) Erecting Dept, American Bridge Co, 1528 Frick Bldg; h, Elberon Apts, 301 S. Winebiddle Ave, Pittsburgh, Pa.......... **Atlantic 4300**

Eaton, Henry T. (May 1923) Mech. Draftsman, Oliver Iron & Steel Corp, S. 10th & Muriel Sts, S.S; h, 910 Ditzler St, Pittsburgh, Pa **Court 0842**

★**Eavenson, Howard N.** (Nov. 1920) President, Eavenson, Alford & Hicks, 1300 Union Trust Bldg; h, 4411 Bayard St, Pittsburgh, Pa.......... **Atlantic 3939**

Ebberts, Alfred R. (March 1927) Engr of Tests, Allegheny County, 519 Smithfield St; h, 1206 Heberton St, Pittsburgh, Pa.......... **Atlantic 4900-Line 141**

Ebersole, F. Leslie (April 1926) Master Mechanic, Park Works, Crucible Steel Co. of America, 30th & Smallman Sts; h, 1308 Hillsdale Ave, South Hills Station, Pittsburgh, Pa.......... **Atlantic 8620**

Eckels, Charles E. (**Junior**) (Nov. 1927) Technical Student, American Telephone & Telegraph Co, 416 Seventh Ave; h, 1108 Gladys Ave, Pittsburgh, Pa.......... **Official 0050-Ext. 450**

★**Eckels, Samuel** (May 1925) Chief Engr, Pennsylvania Department of Highways; h, 925 N. Front St, Harrisburg, Pa.

★**EDGAR, LOUIS C.** (**Vice President**) (Dec. 1915) Chf. Engr, Edgar Thomson Works, Carnegie Steel Co, Braddock; h, 2022 Hampton Ave, Swissvale, Pittsburgh, Pa.......... **Brandywine 2590-Ext. 16**

Edgar, William Claney (May 1921) Wm. C. Edgar Co, 1815 Oliver Bldg; h, 3546 Campus St, Pittsburgh, Pa.......... **Atlantic 0419**

Edstrom, Eric Herbert (**Associate Member**) (Feb. 1929) Machine Designer and Checker, United Engineering & Foundry Co, Farmers Bank Bldg; h, 618 Worth St, Pittsburgh, Pa.......... **Atlantic [illegible]3**

Edwards, Edward Tudor (Nov. 1913) Pres. & Mgr, Vanadium Alloys Stee Co; h, Latrobe, Pa.

Edwards, Vere Buckingham (Oct. 1913) V. P. & Chf. Engr, The Dravo Contracting Co, Dravo Bldg, 300 Penn Ave, Pittsburgh; h, R. D. No. 2, Coraopolis, Pa.................................**Federal 2600**

Egerman, Max (June 1913) Pres, Pittsburgh Contracting & Engineering Co, 811 Rebecca Ave, Wilkinsburg, Pittsburgh, Pa...**Penhurst 1059**

Ehmann, Roy Leon (Sept. 1923) Dist. Mgr, The Superheater Co, 923 Union Trust Bldg; h, 2966 Espy Ave, Dormont, Pittsburgh, Pa...**Atlantic 3799**

Ehrhart, R. N. (Dec. 1928) Consulting Engineer; h, Schenley Apts, Pittsburgh, Pa.

Eichleay, John P. (Feb. 1917) Pres, John Eichleay, Jr. Co, S. 20th St; h, 421 Bailey Ave, Pittsburgh, Pa...................**Hemlock 0420**

Eichleay, Roy Oliver (Dec. 1928) Vice President, John Eichleay Jr. Co. and President Pittsburgh Thermoline Co, 45 S. 20th St; h, 2717 Glenmore Ave, Dormont, Pittsburgh, Pa............**Hemlock 0420**

Eisenbeis, Walter Herman (March 1916) Asst. Sales Mgr, Union Steel Casting Co, 62d & Butler Sts; h, Alger St. & Beechwood Blvd, Pittsburgh, Pa.....................................**Fisk 0456**

Eissler, Robert Frederick (Associate) (Nov. 1927), Dist. Mgr, Chicago Pneumatic Tool Co, 132 Seventh St, Pittsburgh; h, Box 56, Coraopolis, Pa.................................**Atlantic 4286**

Elliott, Byron K. (Feb. 1903) Pres. & Treas, B. K. Elliott Co, 126 Sixth St, Pittsburgh, Pa; h, 33 Castle Shannon Road, Mt. Lebanon, Pittsburgh, Pa....................................**Grant 3660**

Elliott, Robert T. (Oct. 1924) Field Engr, c/o The Koppers Construction Co, c/o Seaboard By-Product Coke Co, Kearny, N. J; h, 17 Webester Place, East Orange, N. J.

Elliott, William S. (Nov. 1901) Pres, The Elliott Company, Frick Bldg; h, Woodland Road, Pittsburgh, Pa..................**Atlantic 5000**

Ellis, Albert Ralph (April 1924) Vice President, Pittsburgh Testing Laboratory, Stevenson & Locust Sts, Box 1115; h, 6963 Edgerton Ave, E. E, Pittsburgh, Pa................................**Grant 3860**

Ellman, Fred (Associate Member) (Oct. 1924) Sales Engr, M. H. Detrick Co, 712-13 Empire Bldg; h, 5846 Alderson St, Pittsburgh, Pa...**Atlantic 1477**

★**Ellman, Louis (Associate Member)** (Dec. 1923) Dist. Mgr, M. H. Detrick Co, 712-713 Empire Bldg; h, 5427 Hobart St, Pittsburgh, Pa...**Atlantic 1477**

Ellsworth, Walter Erwin (June 1929) District Manager, Maxon Premix Burner Company, 414 Bessemer Bldg; h, 222 Grant Avenue, Bellevue, Pittsburgh, Pa.........................**Grant 1941**

Elshoff, R. H. (**Associate**) (Jan. 1925) Sales Engr, Vacuum Oil Co, 717 Liberty Ave; h, 2806 Middletown Road, Crafton, Pittsburgh, Pa.......... **Atlantic 8370**

Elwell, G. Randolph (**Associate Member**) (May 1926) Construction Engr, Pittsburgh Works, Standard Sanitary Mfg. Co, 2801 Preble Ave; h, 3945 Grenet St, N. S, Pittsburgh, Pa.......... **Linden 6070**

★**Ely, Sumner B**. (Sept. 1900) Asst. Prof. of Commercial Engineering, Carnegie Institute of Technology; h, 5122 Pembroke Place, Pittsburgh, Pa.......... **Mayflower 2600**

Emory, Gustavus William (Dec. 1928) Engineer, Pittsburgh Railways Co, 435 Sixth Ave; h, 1423 Hillsdale Ave, Dormont, Pittsburgh, Pa.......... **Grant 7450**

Emrick, Alfred B. (Dec. 1928) Pittsburgh Branch Mgr, Wagner Electric Corp, 5031 Liberty Ave, Pittsburgh; h, 214 North Ave, Emsworth, Pa.......... **Montrose 8204**

Endsley, Louis E. (Dec. 1924) Consulting Engineer; h, 516 East End Ave, Pittsburgh, Pa.......... **Churchill 3846**

Engel, Arthur William (Dec. 1921) Structural Steel Designer, American Bridge Co, 1420 Frick Bldg, Pittsburgh, Pa; h, 628 Mulberry St, Sewickley, Pa.......... **Atlantic 4300**

Enzian, Charles (April 1929) Mining Engineer, The Berwind-White Coal Mining Co, Windber, Pa; h, 707 Fifteenth St, Windber, Pa.

Espenschade, Park William (**Junior**) (Dec. 1927) Railway Equipment Engr, Westinghouse Electric & Mfg. Co, East Pittsburgh, Pa; h, Westinghouse Club, 318 Trenton Ave, Wilkinsburg, Pittsburgh, Pa.......... **Brandywine 1500**

★**Estep, Thomas G.** (Oct. 1927) Associate Professor, Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh; h, 949 S. Braddock Ave, Wilkinsburg, Pittsburgh, Pa.......... **Mayflower 2600**

Etheridge, Harry (March 1926) V. P. & Gen. Mgr, Pittsburgh, Butler & Harmony Cons. Rwy. & Power Co, Harmony, Pa; h, Zelienople, Pa.

Evans, Norman H. (**Student Junior**) (Dec. 1927) Junior Patent Examiner, U. S. Patent Office, Washington, D. C; h, Apt. 602 2025 I Street, N. W, Washington, D. C.

Evans, Thomas Raymond (March 1919) Pres, Diamond Alkali Co, Koppers Bldg; h, 1129 Beechwood Blvd, Pittsburgh, Pa... **Grant 7500**

Evarts, Ralph E. (**Associate Member**) (Dec. 1928) Asst. Ch. Eng, Pittsburgh Equitable Meter Co, 400 Lexington Ave, Pittsburgh, Pa; h, 515 Kelly Ave, Wilkinsburg, Pittsburgh, Pa.... **Churchill 8400**

Everhard, Edgar Philip (April 1917; Dec. 1925) Chief Engr, Freyn Engineering Co, 310 S. Michigan Ave, Chicago, Ill; h, 206 Ulm Place, Hinsdale, Ill.

Ewald, Harry W. (**Associate**) (March 1926) Asst. to Vice President in Charge of Sales, Duquesne Light Co, 435 Sixth Avenue; h, 1548 Tolma Ave, Dormont, Pittsburgh, Pa........ **Grant 4300-Line 421**

Ewalt, Dwight Sapp (Oct. 1927) Sales Engr, The Chapman-Stein Furnace Co; h, 102 Wooster Ave, Mt. Vernon, Ohio.

Faris, Jacob M. (Jan. 1912) Supt. Mechanical & Electrical Depts, Youngstown Sheet & Tube Co; h, 1711 Fifth Ave, Youngstown, O.

Farnham, Thaddeus L. (Dec. 1924) V. P, W. M. McKee, Inc, 436 Oliver Bldg; h, 548 Neville St, Pittsburgh, Pa................ **Atlantic 4658**

Fawell, Joseph Edward, Jr. (March 1908) Asst. to Pres, Mackintosh-Hemphill Co, Point Bldg; h, 5600 Forbes St, Pittsburgh, Pa... **Court 3862**

★**Fear, Thomas George** (Sept. 1923) Genl. Mgr. of Operations, Consolidation Coal Co, Inc, Watson Bldg, Fairmont, W. Va; h, 717 Fairmont Ave, Fairmont, W. Va.

Fechheimer, Carl J. (April 1922) Development Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 5420 Plainfield St, Pittsburgh, Pa.................................... **Brandywine 1500**

Fendner, Willard J. (June 1919) Mechanical Engr, Schaefer Equipment Co, 2710 Koppers Bldg; h, 352 Stratford Ave, Pittsburgh, Pa... **Atlantic 0984**

★**Ferguson, John Ashley** (Dec. 1907; Jan. 1909) John A. Ferguson Engineers, 720 Empire Bldg; h, 1419 N. Euclid Ave, Pittsburgh, Pa... **Atlantic 2371**

Ferguson, John Marshall (April 1916) President, Ferguson Gates Engineering Co, Allen Bldg, Box 669, Beckley, Raleigh Co, W. Va; h, North Kanawha St, Beckley, W. Va.

Ferrara, George Peter (July 1912) Struct. Engr, The Koppers Construction Co, Koppers Bldg; h, 1520 Murray Ave, Pittsburgh. Pa.. **Atlantic 6240**

Fetherling, Herschel G. (**Associate**) (Dec. 1924) Sales Engr, General Electric Co, Oliver Bldg; h, 826 Gearing Ave, Pittsburgh, Pa... **Atlantic 6400**

Feucht, George Charles (Sept. 1918) Chf. Estimator and Designer, Keystone Works, Jones & Laughlin Steel Corp, 3140 Second Ave; h, 432 Orchard St, Mt. Oliver Sta, Pittsburgh, Pa.................... **Court 3240**

★**Fieldner, Arno C.** (April 1919) Chief Engineer and Chief Chemist, Experiments Stations Division, U. S. Bureau of Mines, 17th and F Sts; h, 4739 13th St, N. W, Washington, D. C.

Figee, William Fred (**Associate Member**) (Feb. 1925) Sales Engr, 921 Woodbourne Ave, Brookline, Pittsburgh, Pa........ **Lehigh 2505**

Fink, Samuel I. (Nov. 1923) Gen. Mgr, S. I. Fink Company, 227-2nd Ave; h, 2005 Wendover St, Pittsburgh, Pa.

Finley, Charles A. (April 1903; Sept. 1910) Chairman, Traction Conference Board, First National Bank Bldg; h, 814 Washington Blvd, Pittsburgh, Pa..**Atlantic 2173**

Finley, Norval Howard (April 1903) Chemical Engr, Metropolitan Refining Co. of New York, 921 Empire Bldg; h, 7229 Hermitage St, Pittsburgh, Pa..............................**Hiland 2455-R**

Firth, L. Gerald (March 1924) Gen. Mgr, Firth-Sterling Steel Co, McKeesport, Pa; h, 5575 Northumberland St, Pittsburgh, Pa..**McKeesport 4181**

Fishburn, Cyrus C. (Jan. 1926) Associate Engr, (Civil) National Bureau of Standards, 151 I Bldg, Bureau of Standards; h, Apt. 101, 5402 Connecticut Ave, Washington, D. C.

Fisher, Gordon (Nov. 1927) Pres, Spang-Chalfant Co, Clark Bldg; h, 4 Colonial Place, Pittsburgh, Pa.....................**Atlantic 9230**

★**FISHER, HENRY WRIGHT (Past President 1901)** (Jan. 1895) Consulting Engr, Standard Underground Cable Co; h, 119 Water St, Perth Amboy, N. J.

Fitch, George Carroll (April 1928) Chief Draftsman, Blum, Weldin & Co, Bakewell Bldg; h, 1822 Pioneer Ave, Pittsburgh, Pa....**Court 4997**

Fitzgerald, John Morton (Dec. 1911) Assistant to Chairman, Committee on Public Relations of the Eastern Railroads, 143 Liberty St, New York, N. Y; h, 91 Central Park West, N. Y.

★**Fitzgerald, Thomas** (Dec. 1920) V. P, Pittsburgh Railways Co, 435-6th Ave; h, 5216 Fifth Ave, Pittsburgh, Pa............**Grant 7450-Line 125**

Flanagan, Gerald E. (June 1894) Mech. Engr, Heyl & Patterson, 50 Water St; h, 319 N. St. Clair St, Pittsburgh, Pa.....**Court 0753**

★**Flanagan, Walter N.** (Oct. 1926) Special Engr, Carnegie Steel Co, 1500 Carnegie Bldg; h, 228 Lebanon Ave, Mt. Lebanon, Pittsburgh, Pa. ....**Atlantic 5100**

★**Fleming, Thomas Jr.** (Nov. 1906) Hydraulic and Mech. Engr, P. O. Box 94; h, 704 Amberson Ave, Pittsburgh, Pa.

Flippen, John Philip (Jan. 1927) Dist. Mgr, Farrel Fdry. & Mach. Co. and C. H. Wheeler Mfg. Co, Oliver Building; h, 1237 Murdock St, Pittsburgh, Pa....................................**Atlantic 3697**

Flynn, Francis E. (Junior) (Dec. 1928) Asst. in Engrg. Corps, Conemaugh Div, P. R. R, Pittsburgh, Pa; h, 5625 Baum Blvd, Pittsburgh, Pa...**Grant 6000**

Fohl, Charles Taylor (Junior) (Sept. 1921) Engr, Truscon Steel Co, Miami, Florida.

Fohl, Edward Zinn (Junior) (April 1928) Asst. Engr, Bell Telephone Co. of Penna, 416 7th Ave; h, 322 S. Lang Ave, Pittsburgh, Pa...... ....**Official 0050-274**

★**FOHL, WILLIAM EDWARD (Past President 1926)** (Jan. 1897) Consulting Mining Engineer, 1209 House Bldg; h, 322 S. Lang Ave, Pittsburgh, Pa..**Court 2974**

Foight, Clarence Douglas (Associate Member) (Dec. 1925) Asst. Designing Engr, Bureau of Bridges and Structures, City of Pittsburgh, 301 City-County Bldg; h, 2405 Hobson St, South Hills, Pittsburgh, Pa. ....**Atlantic 3900-188**

★**Forsberg, Rudolf Percy** (May 1921) Principal Asst. Engr, Pittsburgh & Lake Erie R. R. Co, P. & L. E. Terminal Bldg, Pittsburgh, Pa; h, Oliver Road, Emsworth, Pa........................**Court 3201**

Forsstrom, William K. (Oct. 1901) Chief Engr, Wisconsin Steel Works, S. Chicago, Ill; h, Gladstone Hotel, 62.0 Kenwood Ave, Chicago, Ill.

Fortune, J. Robert (Nov. 1905) Mgr. Heating Division, Wickes Boiler Co., Saginaw, Mich; h, 201 E. Kirby St., Detroit, Mich.

Foss, Feodore F. (Jan. 1925) Asst. to Pres, Wheeling Steel Corp, 622 Wheeling Steel Corp. Bldg; h, 111 Bae Mar Place, Wheeling, W. Va.

★**Foster, Samuel D.** (Feb. 1911) Consulting Engr, 1704 Arrott Bldg; h, 5852 Marlborough St, Pittsburgh, Pa....................**Court 2106**

Foster, William Barclay (Associate) (May 1924) Agent, Travelers Ins. Co., St. Paul Fire & Marine Ins. Co., 524 Chamber of Commerce Bldg; h, 1251 Murdock St., Pittsburgh, Pa................**Atlantic 9700**

Fowler, William E. Jr. (March 1926) Chief Engr, Montour Railroad Co, 1711 State St, Coraopolis, Pa; h, 315 Meadow Lane, Sewickley, Pa. ....**Coraopolis 72**

Fownes, William Clark, Jr. (Sept. 1924) Treas. Standard Seamless Tube Co, 313-6th Ave; h, 819 N. Highland Ave, Pittsburgh, Pa........ ....**Atlantic 9230**

Fox, Cyril A. (Feb. 1929) Owner and Manager, Fox Grinder Co, Oliver Bldg; h, 515 Ninth St., Oakmont, Pa...............**Atlantic 1504**

Fox, Charles Louis (Feb. 1903) Asst. Supt, Pennsylvania Water Co, 712 South Ave, Wilkinsburg, Pittsburgh, Pa; h, 375 West Penn Place, Pittsburgh, Pa...............................**Penhurst 0107**

Fox, John Herbert (Feb. 1911) Executive Engr, Pittsburgh Plate Glass Co. 2300 Grant Bldg; h, The University Club, Pittsburgh, Pa..... ....**Atlantic 5600**

Francies, William Hugh (Jan. 1907) Div. Supt, Allegheny County, 519 Smithfield St, Pittsburgh, Pa; h, 32 Center Ave, Emsworth, Pa. ....**Atlantic 4900-Ext. 54**

Francis, Charles B. (Feb. 1928) Director, Bureau of Technical Instruction, Carnegie Steel Co, 214 Carnegie Bldg; h, 815 Bellaire Ave, South Hills, Pittsburgh, Pa....................**Atlantic 5100-316**

Frank, Harry H. (**Associate Member**) (Dec. 1924) Sales Engineer, Manufacturers' Representative, 207 Fulton Bldg; h, 2510 Shady Ave., Pittsburgh, Pa.. . . . . **Atlantic 9730**

Frank, Isaac W. (Feb. 1882) Chairman, Executive Committee, United Engrg. & Fdry. Co, 2301 Farmers Bank Bldg; h, Hotel Schenley, Pittsburgh, Pa . . . . **Atlantic 0863**

Frank, Robert J. (Jan. 1928) V. P. Chg. Sales, Copperweld Steel Co, Glassport, Pa; h, 1336 Inverness Ave, Pittsburgh, Pa . . . . **Glassport 361**

Frank, William Klee (Sept. 1913) V. P, Copperweld Steel Co, Glassport, Pa; h, 5535 Aylesboro Ave, Pittsburgh, Pa . . . . **Glassport 361**

★**Frauenheim, Aloysius M.** (**Associate Member**) (Dec. 1927) Sales Engr, Standard Auto-Tite Joints Co., 916 Forbes St; h, 110 Bigham St, Pittsburgh, Pa . . . . **Atlantic 6615**

Frazer, C. E. (Dec. 1927) Pres, Simplex Engineering Co, Washington Trust Bldg; h, 417 E. Bean St, Washington, Pa.

Frease, John B. (April 1921) Practising Engr, 510-11 Shields Bldg, 822 Wood St; h, 435 Franklin Ave, Wilkinsburg, Pittsburgh, Pa . . . . **Churchill 3628**

Frederick, Paul (Oct. 1928) Electrical Engineer, General Electric Co., Oliver Bldg, Pittsburgh, Pa; h, Osborne Lane, Sewickley, Pa. . . . . **Atlantic 6400**

Freeman, Andrew Y. Jr. (Sept. 1925) Asst. Erection Engr, Fort Pitt Bridge Works, Oliver Bldg; h, 3510 Perrysville Ave, Pittsburgh, Pa. . . . . **Atlantic 0654**

Freeman, Henry Raymond, Jr. (**Associate**) (Jan. 1929) Mgr. Tubular Dept, National Supply Co, 319 Frick Bldg, Pittsburgh, Pa; h, 23 Linden Place, Sewickley, Pa . . . . **Grant 2328**

Freeman, Perry John (March 1924) Chief Engr, Bureau Tests and Specifications, Allegheny County, 519 Smithfield St; h, 264 Orchard Drive, Mt. Lebanon, Pittsburgh, Pa . . . . **Atlantic 4900-Ext. 141**

Freund, Jacob deS. (June 1911) Secy. & Gen. Mgr, American Cement Tile Mfg. Co, 826 Oliver Bldg; h, 1088 Shady Ave, E. E, Pittsburgh, Pa. . . . . **Atlantic 2480**

Friederici Max (Nov. 1921) Chief Draftsman, Weirton Steel Co; h, 304 Belleview Blvd, Steubenville, O.

Frink, Robert L. (Oct. 1904) Cons. Engr, Frink Laboratories, 420 S. Broad St; h, 1184 N. Columbus St, Lancaster, O.

Frohman, E. D. (April 1896; March 1915) Vice President, The S. Obermayer Co, 33rd & A.V.R.R; h, 245 Melwood St, Pittsburgh, Pa . . . . **Atlantic 6547**

Frohrieb, Louis C. (July 1910) Federal Engrg. Co, 1420 Investment Bldg, 239 Fourth Ave; h, 1107 Peermont Ave, Dormont, Pittsburgh, Pa . . . . **Court 2672**

Frys, D. W., Jr. (**Junior**) (Nov. 1928) Mining Engr, 16 S. Franklin St, Washington, Pa.

Fuhs, William F. (Oct. 1925) Secy, Pihl & Miller Inc, 637 Wabash Bldg; h, 1214 Biltmore Ave, Dormont, Pittsburgh, Pa .... **Court 1670**

★**Fuller, Samuel L.** (April 1910; Jan. 1922) V. P, John F. Casey Co, Box 1753, Pittsburgh, Pa; h, 1159 King Ave, E. E. Pittsburgh, Pa. .... **Sterling 1400**

Fullman, James Miller Grant (Dec. 1901) Genl. Designing Engr, National Electric Products Corp, 14th St, Ambridge, Pa; h, 904 Beaver St, Sewickley, Pa .... **Ambridge 15**

★**Fulton, James Stewart** (June 1923) Special Repr, Ingersoll-Rand Co, 706 Chamber of Commerce Bldg, Pittsburgh, Pa; h, 431 Maple Lane, Edgeworth, Shields P. O, Pa .... **Atlantic 9070**

Fusca, Emil A. (Jan. 1927) Draftsman, Pittsburgh Plate Glass Co, Grant Bldg; h, P. O. Box 174, Perrysville, Pa .... **Atlantic 5600**

★**Gadsby, G. M.** (March 1924) Pres. Utah Power & Light Co, Kearns Bldg, Salt Lake City, Utah; h, 808 E. S. Temple St, Salt Lake City, Utah.

Gaines, Edward C. (April 1916) Engr, Mead Morrison Mfg. Co, Monadnock Block; h, 5046 Winthrop Ave, Chicago, Ill.

Gallinger, Walter N. (Dec. 1922) Mining Engr, 344 Semple St, Pittsburgh Pa.

Gamble, Earl Rolland (**Associate**) (March 1926) Sales Engr, Garlock Packing Co, 339 Boulevard of Allies, Pittsburgh; h, 724 Shady Drive East, Mt. Lebanon, Pittsburgh, Pa .... **Court 2222**

Gare, Marshall Stearns (Dec. 1927) Sales Engr, Hagan Corporation, 502 Bowman Bldg; h, 6943 McPherson Blvd, Pittsburgh, Pa .... **Court 4724**

Garratt, Frank (Feb. 1912; Oct. 1925) Metallurgical Engr, Universal Steel Co, Bridgeville, Pa; h, 271 Jefferson Drive, South Hills Br, Pittsburgh, Pa .... **Bridgeville 34**

★**GASCHE, FERDINAND GUY** (**Silver Medal 1913**) (Feb. 1912) Combustion Engr, Bethlehem Steel Co, Lackawanna Plant, Lackawanna, N. Y; h, 228 Anderson Place, Hamburg, N. Y.

Gass, Karl William (April 1920) Engr, Stephens-Adamson Mfg. Co, 1624 Oliver Bldg; h, 5512 Beverly Place, Pittsburgh, Pa ... **Atlantic 0490**

Gealy, E. J. (**Associate**) (Feb. 1929) Pittsburgh Coal Co, Oliver Bldg; h, 2574 Beechwood Blvd, Pittsburgh, Pa .... **Atlantic 2181**

Geeseman, Delbert B. (April 1922) Asst. Mgr, Standard Tin Plate Co, Canonsburg, Pa; h, 207 W. Pike St, Houston, Pa .. **Canonsburg 65**

Gerber, Carl B. (Jan. 1929) Sales Engineer, Concrete Engineering Co, 1213 Plaza Bldg; h, 1622 Duffield St, Pittsburgh, Pa .... **Atlantic 0619**

Gerber, Christian G. (Nov. 1911) Cons. Engr, 805 Federal Reserve Bank Bldg; h, 3555 Gerber Ave, N. S. Pittsburgh, Pa...... **Atlantic 8956**

Gerwig, Frederick Henry Nicholas (Feb. 1902) Mill Supt, Carnegie Steel Co, Edgar Thomson Works; h, 901 Kirkpatrick Avenue, Braddock Pa.. **Brandywine 2446**

Gerwig, Homer Christian (Oct. 1928) Sales Engineer, National Tube Co, 1825 Frick Bldg; h, 5631 Elgin Ave, Pittsburgh, Pa.. **Atlantic 2500**

Giles, David J. (**Associate Member**) (April 1917) Metallurgist, Latrobe Electric Steel Co; h, 621 Walnut St, Latrobe, Pa....... **Latrobe 650**

Gill, David Donald (Feb. 1924) Manufacturers' Agent, 713 Commonwealth Bldg. Annex; h, 1608-A Denniston Ave, Squirrel Hill, Pittsburgh, Pa.. **Court 0493**

Gillespie, Thomas James, Jr. (Sept. 1915) Secy. & Treas, Lockhart Iron & Steel Co, Box 1243; h, 619 S. Negley Ave, Pittsburgh, Pa. **Federal 1081**

Girdler, Tom M. (Oct. 1928) President, Chairman of Board, Republic Steel Corp, Cleveland, Ohio; h, Academy Ave, Sewickley, Pa.

Giroux, Fred J. (**Junior**) (Dec. 1928) Genl. Mgr. Trane Company; h, 488 Ella St, Wilkinsburg, Pittsburgh, Pa.

Glass, John (Sept. 1912) Chief Engr, Carnegie Natural Gas Co, Box 751; h, Sherman Ave, Waynesburg, Pa..................... **Waynesburg 622**

Glass, Roy Charles (April 1915) Engr, Carnegie Natural Gas Co, Box 716, Waynesburg, Pa.............................. **Waynesburg 773**

Gleason, Donald Thomas (May 1921) Works Mgr, Standard Steel Spring Co; h, 1052 Hiland Ave, Coraopolis, Pa.......... **Coraopolis 1100**

Gleason, William P. (Jan. 1905) Gen. Supt, Indiana Steel Co; h, 670 Jackson St, Gary, Ind.

Godard, Ray S. (April 1926) Engr, H. L. Dixon Co, Box 140, Carnegie, Pa; h, Mt. Lebanon Blvd, Mt. Lebanon, Pittsburgh, Pa.. **Walnut 0403**

★**Godfrey, Edward** (June 1906) Struct. Engr, Robert W. Hunt Co, Professional Bldg; h, 630 Kirtland St, Pittsburgh, Pa.... **Atlantic 3950**

Goodale, Stephen Lincoln (April 1910) Professor of Metallurgy, University of Pittsburgh; h, 1156 Murrayhill Ave, Pittsburgh, Pa.. **Mayflower 3500**

Goodspeed, George M. (March 1912) Metallurgist, National Works, National Tube Co; h, 1818 Packer St, McKeesport, Pa.. **McKeesport 4144**

Goodwin, Irving Dean (**Associate Member**) (Feb. 1925) Chief Draftsman, Pittsburgh-Des Moines Steel Co, Neville Island P. O; h, 1514 Dormont Ave, S. H. Branch, Pittsburgh, Pa........... **Federal 3000**

Goodwin, Walter Cook (Associate Member) (May 1921) Mgr, Renewal Parts, Engineering Dept, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 6032 St. Marie St, Pittsburgh, Pa........ ....**Brandywine 1500**

Gordon, Bennett Taylor (Junior) (March 1926) Designer, Bureau of Bridges, Allegheny County, 519 Smithfield St; h, 6753 Thomas Blvd, Pittsburgh, Pa.................................**Atlantic 4900**

Gordon, Harold L. (Feb. 1920) Asst. Gen. Mgr, Pittsburgh Limestone Co, Johnson Bldg; h, 2211 N. Highland Ave, New Castle, Pa...... ....**New Castle 2620**

★**GRACE, SERGIUS P. (Past President 1913)** (Jan. 1903) Asst. Vice Pres, Bell Telephone Laboratories, Inc, 463 West St; h, 162 W. 54th St, New York, N. Y.

Graf, Julius E. (Feb. 1926) Asst. Chief Engineer, American Sheet & Tin Plate Co, Box 62, 1222 Frick Bldg, Pittsburgh, Pa; h, 1019 Hamilton Ave, Avalon, Pittsburgh, Pa..................**Atlantic 1300**

Graham, Herbert W. (Oct. 1928) Cenl. Metallurgist, Jones & Laughlin Steel Corp; h, 5437 Ellsworth Avenue, Pittsburgh, Pa..**Court 3240**

Graham John A. (Sept. 1924) Supt. Buildings & Grounds, Shady Side Academy, Drawer G, Oakland P.O; h, 228 Fourth St, Aspinwall, Pittsburgh, Pa.................................**Sterling 2400**

Gray, Thomas William (Sept. 1929) Supt. of Mechanical Equipment, Pittsburgh Coal Co, Library, Pa; h, Heidelberg, Pa.

Grayson, Sidney Alwyn (April 1912) Pres, Jessop Steel Co; h, 65 LeMoyne Ave, Washington, Pa.........................**Washington 2140**

Greenberg, Morris (Nov. 1929) Manager, Pittsburgh Office, Bailey Meter Company, 402 Oliver Bldg; h, Haddon Hall, 4730 Center Ave, Pittsburgh, Pa.................................**Atlantic 2530**

Gregg, Lester Osborne (Feb. 1929) Sales Engineer, Elliott Company, 718 Frick Bldg, Pittsburgh, Pa; h, 34 West Cardott St, Ridgway, Pa.. ....**Atlantic 5000**

Gressly, Oscar E. (Dec. 1910) Retired, 434 East End Ave, Beaver, Pa. ....**Beaver 1268-R**

Greve, Edgar Eugene (Sept. 1912) Chief Engr, Oil Well Supply Co, 2201 Clark Bldg, Pittsburgh, Pa; h, 152 Grant Ave, Bellevue Branch, Pittsburgh, Pa.................................**Atlantic 7980**

Grier, Louis N. (Associate) (Feb. 1925) Electrical Engr, Aluminum Co. of America, New Kensington, Pa; h, 365 Riverview Drive, Parnassus, Pa.

Griffiths, Edward McCullough (Dec. 1928) Engineering Dept, Republic Iron & Steel Co; h, 58 Roslyn Drive, Youngstown, Ohio.

Griggs, Thomas Newell (Junior) (Jan. 1928) Attorney at Law, 732 Oliver Bldg; h, 943 S. Braddock Ave, Wilkinsburg, Pittsburgh, Pa. . . . . **Atlantic 2370**

Grimes, L. W. David (Junior) (April 1929) Draftsman, Westinghouse Electric & Mfg. Co, East Pittsburgh, Pa; h, 6200 Olivant St, Pittsburgh, Pa. . . . . **Brandywine 1500**

Grimm, Bruce F. (Oct. 1928) Electrical Engineer, The Koppers Coal Company, 1005 Koppers Bldg; h, 3036 Earlsmere Ave, P. O. Box 124, South Hills Station, Pittsburgh, Pa. . . . . **Atlantic 6240**

Grobstein, Albert (Feb. 1924) Patent Engr, 414 Ouray Bldg; h, 1300 Taylor St, N. W. Washington, D. C.

Grose, James H. (Feb. 1909) Pres, Brier Hill Steel Co; h, 17 Club Ave, Carrick, Pa.

Growdon, J. P. (March 1928) Hydraulic Engr, Aluminum Co. of America, 2400 Oliver Bldg, Pittsburgh, Pa. . . . . **Atlantic 4545**

Guildbrandsen, Peter (May 1916) Draftsman, Aetna Standard Engineering Co, 809 Home Savings & Loan Bldg, Youngstown, Ohio; h, P. O. Box 504, Youngstown, Ohio.

Gulick, Henry (Feb. 1903) Pres, Gulick-Henderson Co. Inc, 19 West 44th St, New York, N. Y; h, 45 Alida St, Yonkers, N. Y.

Gunther, Felix A. (Nov. 1924) Sales Engr, Direct Control Valve Co, 1007 Diamond Bank Bldg; h, R. F. D. No. 9, Box 137, S. H. Pittsburgh, Pa. . . . . **Atlantic 7435**

Guthrie, James McMurchie (Associate Member) (June 1926) Patent Engineer, Christy, Christy & Wharton, 2203 Farmers Bank Bldg; h, 206 Forbes Bldg, Pittsburgh, Pa. . . . . **Atlantic 0386**

Guy, Frederick William (Associate Member) (April 1929) Salesman, Walworth Company, 604 Chamber of Commerce Bldg, Pittsburgh, Pa; h, 104 Lakewood Ave, West View, Pa. . . . . **Atlantic 8741**

Haag, Louis William (May 1923) Chief Engineer, Michigan Steel Corp, Ecorse, Detroit, Mich; h, 253 Emmons Blvd, Wyandotte, Mich.

Haas, Charles (Associate Member) (June 1928) Pres, The Chas. Haas Co, Cuyahoga Falls, O; h, 423 Thirteenth St, Cuyahoga Falls, O.

Hadley, Edward Thomas (Nov. 1921) Draftsman, Ohio Works, Carnegie Steel Co; h, 3125 Idlewood St, Youngstown, O.

Haertlein, Albert (Associate Member) (May 1925) Associate Prof. of Civil Engineering, Harvard University, Pierce Hall, Cambridge, Mass; h, 80 Grozier Road, Cambridge, Mass.

HAGGART, CECIL NEIL (Chairman Civil Section) (Oct. 1903; May 1912) Consulting Structural Engr, Private Practice, 522-524 335 Fifth Ave; h, 10 Hazel Drive, Mt. Lebanon, Pittsburgh, Pa. . **Atlantic 5349**

Haines, J. Edgar (June 1920) Mech. Engr, Hammer Welding Dept, Christy Park Works, National Tube Co, McKeesport, Pa; h, 989 Greenfield Ave, Pittsburgh, Pa. . . . . **McKeesport 5128**

Haines, William L. R. ((Dec. 1928) Asst. Engr. Penna. System, Room 1124, Penna. Station, Pittsburgh, Pa; h, 5437 Ellsworth Ave, Pittsburgh, Pa. . . . . **Grant 6000-Ext. 95**

Haldeman, James F. (Feb. 1917) Pres. J. F. Haldeman Co, 5941 Baum Blvd; h, 1210 S. Negley Ave, Pittsburgh, Pa. . . . . . . **Montrose 7198**

Hale, William Thurber (May 1926) Engineer, American Rolling Mill Co, Ashland, Ky; h, 1800 Lexington Avenue, Ashland, Ky.

Hall, William Ford (Feb. 1910) Dist. Mgr, Raymond Concrete Pile Co, Inc, 1501 Union Bank Bldg; h, 1060 Morewood Ave, Pittsburgh, Pa. . . . . **Court 1436**

Haller, Fred E. (**Associate**) (June 1929) Manager, Mt. Lebanon Garage Co, 600 Washington Road; h, 616 Washington Road, Pittsburgh Pa. . . . . **Lehigh 0565**

Haller, Henry E. (May 1921) Pres, National Valve & Mfg. Co, 31st St. & Liberty Ave; h, 415 S. Pacific Ave, Pittsburgh, Pa. . . . **Atlantic 6730**

Hallett, Henry McLellan (Feb. 1909) District Manager, Pennsylvania Crusher Co, 1445 Oliver Bldg, Pittsburgh, Pa; h, 324 Forest Ave, Ben Avon, Pittsburgh, Pa. . . . . **Atlantic 0839**

Hallgren, Emil (Feb. 1891; Jan. 1912) Private Work, 617 Ridgewood Ave, Pittsburgh, Pa.

Hallock, John Keese (**Associate**) (Feb. 1909) Asst. Sales Mgr, Universal-Atlas Cement Co, 518 Frick Bldg, Pittsburgh, Pa; h, 258 Grant St, Sewickley, Pa. . . . . **Atlantic 2087**

Hallock, John Wilson Wishart (Jan. 1911) Professor & Head, Industrial Engineering Dept. and Director, Cooperative Work, School of Engineering, University of Pittsburgh, 101 Thaw Hall; h, 348 S. Linden Ave, Pittsburgh, Pa. **Mayflower 3500**

Hamilton, William Bovard (April 1925) Construction Engr, South Side Wks, Jones & Laughlin Steel Corp, 2709 Carson St; h, 1038 Chelton Ave, Brookline, Pittsburgh, Pa. . . . . **Hemlock 0401-Ext. 368**

Hammer, Lewis E. (Dec. 1925) Asst. to Gen. Supt, The Elliott Co, Jeannette, Pa; h, 612 Brandon St, Greensburg, Pa. . . . . **Jeannette 566**

Hammill, Fred W. (**Associate Member**) (Feb. 1922) Draftsman, Engineering Dept, South Side Works, Jones & Laughlin Steel Corp, 27th & Carson Sts; h, 1229 Straka St, Corliss Sta, Pittsburgh, Pa. . . . . **Hemlock 0401-Ext. 369**

Hammond, James H. (**Associate**) (April 1913) 1819 Oliver Bldg; h, Woodland Road, Pittsburgh, Pa. . . . . **Atlantic 0736**

Handloser, Bertram F. (**Associate Member**) (Dec. 1924) Asst. Mill Mgr, Dilworth, Porter & Co, 4th & Bingham Sts; h, 5734 Northumberland St, Pittsburgh, Pa. . . . . **Hemlock 0740**

★**HANDY, JAMES OTIS (Past President 1912)** (Nov. 1896) Director of Chemical & Metallurgical Investigations, Pittsburgh Testing Laboratory, Locust & Stevenson Sts, Box 1115, Pittsburgh, Pa; h, 49 Emerson Ave, New Rochelle, N. Y.................. **Grant 3860**

Hansen, William Charles (Feb. 1924) Sales Engr, A. Stucki Co, 419 Oliver Bldg; h, 1115 Davis Ave, Pittsburgh, Pa............ **Atlantic 1250**

Hanst, John Faber (Dec. 1925) Acting Mgr, Ingersoll-Rand Company, 11 Broadway, New York, N. Y.

Harris, Benjamin F. (Sept. 1915) President, Oil Well Supply Co, Clark Bldg; h, 1117 S. Negley Ave, Pittsburgh, Pa......... **Atlantic 7980**

Harris, Charles A. (Associate) (March 1927) Chief of Stores, Philadelphia Co. and Subsidiary Companies, 435 Sixth Ave; h, 7502 Church Ave, Ben Avon, Pittsburgh, Pa.......................... **Grant 4300**

Harrop, Harry Stewart (Jan. 1902) Member of Firm, Harrop & Hopkins, 801 Home Trust Building, Pittsburgh; h, 436 South Ave, Wilkinsburg, Pittsburgh, Pa.............................. **Atlantic 3824**

Harshbargar, Elmer Dwight (Oct. 1911) Pres, The Pitt Construction Co, 911 Empire Bldg; h, 239 Gladstone Road, Pittsburgh, Pa...... .... **Atlantic 5480**

Harter, Isaac (Sept. 1924) V. P, Babcock & Wilcox Co, 85 Liberty St, New York, N. Y; h, 45 E. 82nd St, New York, N. Y.

Harton, Erskine Elliott (Feb. 1914) Chf. Draftsman, Treadwell Construction Co, Midland, Pa; h, 408 Fair Ave, Beaver, Pa...... **Midland 62**

Hartson, Dorr Parmelee (Sept. 1922) Mgr. System Development Dept, Equitable Gas Co, 435 Sixth Ave; h, 1445 Center St, Wilkinsburg, Pittsburgh, Pa.......................... **Grant 7600—Ext. 93**

★**Harvey, Clarke Kennerley** (Dec. 1927) Principal Asst. Engr, Bureau of Bridges, County Dept. of Public Works, 519 Smithfield St; h, 933 Fordham St, S. H. Sta, Pittsburgh, Pa.......... **Atlantic 4900-202**

Haslam, Edwin H. (May 1900) District Mgr, Elliott Co, 1129 Conway Bldg, Chicago, Ill.

Hatton, Merle W. (June 1913) Res. Engr, Roll & Machine Works, American Sheet & Tin Plate Co; h, 188-33rd St, N. W, Canton, O.

★**HAWLEY, WILLIAM CHAUNCEY (Past President 1920)** (Jan. 1903) Chief Engr. & Gen. Supt, Pennsylvania Water Co, 712 South Ave, Wilkinsburg, Pittsburgh, Pa; h, 131 Beech St, Edgewood (Swissvale Sta.), Pa................................. **Penhurst 0107**

Haworth, Mack E. (Jan. 1926) Chief Engr, Hillman Coal & Coke Co, 2307 First National Bank Bldg; h, 16 Stewart Ave, Carrick, Pittsburgh, Pa... **Atlantic 2620**

★**Haydock, Winters** (May 1921) Directing Engr, Dept. of City Transit, City of Pittsburgh, 906 City-County Bldg; h, 2524 Beechwood Blvd, Pittsburgh, Pa.............................**Atlantic 3900**

Hazeltine, Harold L. (April 1926) Engr. of Insulation, The Sterling Varnish Co, Haysville, Allegheny Co, Pa; h, 210 Center Ave, Emsworth, Pa. ....**Sewickley 1550**

Heald, Kenneth Conrad (Jan. 1926) Staff Geologist, The Gulf Refining Companies, 1161 Frick Bldg. Annex, Diamond St; h, 100 Gladstone Road, Squirrel Hill Sta, Pittsburgh, Pa.............**Atlantic 5300**

Hecht, Max (June 1919) Chief Chemist, Duquesne Light Co, 2101 Beaver Ave, N. S; h, 6432 Darlington Road, Pittsburgh, Pa............ ....**Grant 4300-Ext. 549**

Heckmon, Charles J. (March 1919) Chf. Draftsman, Spang Chalfant & Co, Etna, Pa; h, 129 6th St, Aspinwall, Pittsburgh, Pa **Sterling 0740**

Hefft, Joseph S. (April 1926) Dist. Mgr. Robins Conveying Belt Co, 942 Union Trust Bldg; h, 1031 King Ave, Pittsburgh, Pa..**Atlantic 5548**

Heichert, Herman S. (Feb. 1913) Chief Engr, Pittsburgh Plate Glass Co, 2300 Grant Bldg; h, Ruskin Apts, 120 Ruskin Ave, E. E. Pittsburgh, Pa..**Atlantic 5600**

Heinle, Albert W. (Nov. 1921) Consulting Metal-Rolling Engr, 27 Taylor St, Crafton Branch, Pittsburgh, Pa..................**Walnut 2700**

Helick, Reuben H. (Nov. 1928) Maintenance Engr, Bridges, Allegheny County, Dept. of Public Works, 519 Smithfield St, Pittsburgh, Pa; h, 312 Locust St, Swissvale, Pittsburgh, Pa...... **Atlantic 4900-42**

★**HELLER, LEWIS W.** (**Silver Medal 1923**) (May 1921) Asst. Chief Engr, Fuller Lehigh Co, Fullerton, Pa; h, 1127 Hamilton St, Allentown, Pa.

Hellmund, Rudolph E. (Dec. 1926) Chief Electrical Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 7510 Trevanion Ave, Swissvale, Pittsburgh, Pa......................**Brandywine 1500**

Hempsted, James Gardiner (Sept. 1904) V. P. Continental Bolt & Iron Works, 2225 W. 43rd St; h, 5007 Dorchester Ave, Chicago, Ill.

Henderson, Adelbert Andrew (Feb. 1925) Construction Engr, Bureau of Bridges, Dept. Public Works, Allegheny County, 519 Smithfield St, Pittsburgh; h, 603 Hill Ave, Wilkinsburg, Pittsburgh, Pa. ....**Atlantic 4900**

Henderson, David (**Associate Member**) (April 1914; March 1923) Sales Engr, Dravo-Doyle Co, 300 Penn Ave; h, 334 Orchard Drive, S. H. Branch, Pittsburgh, Pa.............................**Court 5400**

Henderson, Herbert (March 1929) Manager of Construction, Gulf Refining Co, P. O. Box No. 1214; h, Morewood Gardens, Morewood Ave, Pittsburgh, Pa.................................**Atlantic 5300**

Hendrickson, George L. (March 1929) Designing Engr, Bureau of Water, City of Pittsburgh, 309 City-County Bldg, Pittsburgh; h, 28 Bonvue St, Observatory Station, Pittsburgh, Pa...... **Atlantic 3900-Ext. 66**

Hendrix, Walter Willits (Feb. 1913) Vice President, Pittsburgh-Des Moines Steel Co, Neville Island; h, 5500 Beverly Place, E. E, Pittsburgh, Pa.. **Federal 3000**

Hengstenberg, Paul M. (Dec. 1917) Head, Experimental Dept, Westinghouse Elec. & Mfg. Co, East Pittsburgh; h, 508 Jeannette St, Wilkinsburg, Pittsburgh, Pa.......................... **Brandywine 1500**

Henrici Frederick W. (May 1922) Asst. Engr, Erecting Dept. American Bridge Co, 1526 Frick Bldg; h, 1114 Portland St, Pittsburgh, Pa. .... **Atlantic 4300**

★**Henry, John Byron** (May 1911) V. P. Union Steel Casting Co, 62nd and Butler Sts, Pittsburgh; h, 201 Brilliant Ave, Aspinwall, Pittsburgh, Pa.. **Fisk 0456**

Hensen, Emil (Sept. 1908) Engr, Jones & Laughlin Steel Corp, 2nd Ave. & Ross St, Pittsburgh; h, 1107 Woodlawn Drive, Coraopolis, Pa.... .... **Court 3240**

Heppenstall, Charles William (Jan. 1921) President, Heppenstall Forge & Knife Co, 4620 Hatfield St; h, West Woodland Road, Pittsburgh, Pa.. **Fisk 0800**

Heppenstall, Samuel B. (Oct. 1913) V. P. & Chief Engr, Heppenstall Forge & Knife Co, 4620 Hatfield St; h, 1217 Heberton St, Pittsburgh, Pa.. **Fisk 0800**

Herpel, Harry Conrad (Sept. 1919) Supt. Pipe Mills, National Works, National Tube Co; h, 1250 Park St, McKeesport, Pa.......... .... **McKeesport 4144**

Herr, Benjamin M. (March 1918) Owner, Herr-Harris Co, Sales Engineers, 910 Fulton Bldg; h, 571 Briar Cliff Road, Pittsburgh, Pa...... .... **Grant 6475**

Herr, Edwin M. (March 1900) Vice Chairman, Westinghouse Elec. & Mfg. Co, 150 Broadway, New York; h, 1035 Fifth Avenue, New York, N. Y.

Herrmann, John LeRoy (Oct. 1929) Sales Engineer, American Gas Accumulator Company, 2882 West Liberty Avenue, South Hills Station, Pittsburgh, Pa; h, 325 McCully Street, Mt. Lebanon, Pittsburgh, Pa.................................. **Lehigh 0600**

Herrman, Theodore Joseph (Sept. 1919) Mechanical Designer, National Tube Co, National Works, Fourth Ave; h, 2313 Banker St, McKeesport, Pa.................................. **McKeesport 21744**

Hersperger, Wade Wilson (Associate) (May 1922) Mgr. Chas. Bruning Co. Inc, 646 Grant St, Pittsburgh, Pa; h, 103 Grant Ave, Bellevue, Pittsburgh, Pa.................................. **Atlantic 8682**

Hertzler, Samuel P. (May 1921) Chief Engr, B. Floersheim & Co, 622 Farmers Bank Bldg; h, 3321 Francisco St, Corliss Sta, Pittsburgh, Pa..**Atlantic 2224**

Hess, Charles Edward (Oct. 1924) Structural Engr, Private Practice, McCance Block; h, 47 Dallas Ave. Ingram, Pittsburgh, Pa...**Atlantic 3630**

Hess, Oliver P. (April 1921) Practising Engr, 400-401 Deposit National Bank Bldg; h, 415 S. Church St, DuBois, Pa............**Bell 1165**

Hester, E. A. (Jan. 1927) Planning Engr, Duquesne Light Co, 435 Sixth Ave; 7448 Penfield Court, Pittsburgh, Pa.............**Grant 4300**

Hezlep, John H. (June 1928) Sales Engr, Lathrop-Hoge Gypsum Const. Co, 207 Fulton Bldg; h, 506 Rossmore St, Brookline, Pittsburgh, Pa..**Atlantic 9730**

Hicks, John Robert (Oct. 1924) Civil & Mining Engr, Eavenson, Alford & Hicks, 1300 Union Trust Bldg; h, 516 Grandview Ave, Mt. Washington, Pittsburgh, Pa............................**Atlantic 3939**

Higgins, Robert Warren (Junior) (June 1927) Service Engr, M. H. Detrick Co, 712 Empire Bldg; h, 4811 Baum Blvd, Pittsburgh, Pa...**Atlantic 1477**

Higgins, Thomas (Feb. 1916) Gen. Supt, City Mills, Carnegie Steel Co, 35th St, Pittsburgh, Pa; h, Glenshaw, Pa...........**Atlantic 8862**

Hildreth, Harold Francis (Associate Member) (June 1927) Stoker Engr, Westinghouse Elec. & Mfg. Co, Grant Bldg; h, Webster Hall, Pittsburgh, Pa....................................**Atlantic 8400**

Hiles, John D. (April 1918) John D. Hiles Co, Oliver Bldg, Pittsburgh, Pa; h, 1031 Mifflin Ave, Edgewood, Pittsburgh. Pa........**Atlantic 1254**

Hill, B. Houston (Jan. 1913) President, Steam Equipment Mfg. Co, 428 Jenkins Arcade Bldg; h, 5818 Kentucky Ave, Pittsburgh, Pa. ....**Atlantic 6509**

Hill, Charles Montgomery (Associate) (Dec. 1926) Electrical Engr, New York Power & Light Corp; h, University Club, Albany, N. Y.

Hill, Frank L. (April 1921) 514 Walnut St, McKeesport, Pa.

Hill, Harold Otto (Feb. 1925) Contracting Engineer, Riter-Conley Works of the McClintic-Marshall Co, Box 939, Pittsburgh, Pa; h, 111 Ninth St, Aspinwall, Pittsburgh, Pa......................**Atlantic 2562**

Hill, Harry C. (Feb. 1925) h, 201 W. Hutchinson Ave, Edgewood, Pittsburgh, Pa....................................**Penhurst 1545**

Hiller, August (Jan. 1924) Industrial Engr, Universal Steel Co, Bridgeville, Pa; h, 3015 Brownsville Road, Mt. Oliver, P. O., Pittsburgh, Pa....................................**Carrick 1356-M**

Hilton, Winfield Reed (Junior) (Sept. 1926) Draftsman, Pittsburgh-Des Moines Steel Co, Neville Island, Pittsburgh, Pa; h, 1045 Ridge Ave, Coraopolis, Pa..................................**Federal 3000**

Hinnau, Webster (April 1921) Engr, McCully Engineering Co, 709 Berger Bldg; h, 3500 Simen Ave, N. S, Pittsburgh, Pa.........**Court 4573**

Hirsh, William L. (Nov. 1926) Principal Asst. Engr, Bureau of Water, City of Pittsburgh, 311 City-County Bldg; h, 727 Fordham St, Brookline, S. H. Sta, Pittsburgh, Pa....................**Atlantic 3900-Ext. 43**

Hirtle, William A. (April 1921) Registered Engineer in Private Practice, 7619 Bennett St, Pittsburgh, Pa..................**Churchill 1412**

★**HOBBS, JAMES CLARENCE** (**Silver Medal 1923**) (Jan. 1916) Supt. of Power, Diamond Alkali Co; h, 126 Wood St, Painesville, O.

Hockensmith, Wilbur Darwin (Sept. 1915) Pres. & Gen. Mgr, Hockensmith Wheel & Mine Car Co, Penn, Pa; h, Irwin, Pa..**Jeannette 700-01**

★**Hodgkinson, Francis** (April 1897) Consulting Mechanical Engr, Westinghouse Elec. & Mfg. Co, S. Philadelphia Sub-Sta, Lester, Pa; h, Walnut Park Plaza, 63rd and Walnut Sts, Philadelphia, Pa.

Hodgson, Alfred Edward (June 1929) Representative, Allen & Garcia Company, Consulting Engineers, 8 Market Street, Pittsburgh, Pa; h, 843 Holland Avenue, Pittsburgh, (Wilkinsburg Station) Pa...... ....**Court 1877**

★**HOEVELER, JOHN A.** (**Chairman Illuminating Engineers' Section**) (June 1926) Mgr. Engineering Dept, Pittsburgh Reflector Co, 304 Ross St; h, Central Square Apts, B-1, Mt. Lebanon, Pittsburgh, Pa. ....**Court 0571**

Hoffman, James Thomas (Sept. 1926) Patent Engr, U. S. Patent Office, Div. 13, 154 Annex; h, Park Lane Apt. No. 1016, 21st and Pennsylvania Ave, Washington, D. C.

Hoffman, Walter George (March 1929) Chief Engr, Brooke L. Jarrett & Co, 704 Law and Finance Bldg; h, 101 W. Shady Drive, Mt. Lebanon, Pittsburgh, Pa........................**Atlantic 8439**

Hoffman, William Guy (March 1926) Chf. Estimator, American Sheet & Tin Plate Co, Frick Bldg, Pittsburgh, Pa; h, 3 Rosslyn Road, Carnegie, Pa................................**Atlantic 1300**

Holbrook, Elmer Allen (Oct. 1927) Dean, Schools of Engineering and Mines, University of Pittsburgh; h, 1543 Shady Ave, Pittsburgh, Pa......................................**Mayflower 3500**

Holiday, Harry (Nov. 1923) Genl. Supt, American Rolling Mill Co, Butler Works, Butler, Pa.................................**Butler 2791**

Holland, William Jacob (Dec. 1888) Director Emeritus, Carnegie Museum, Pres, Carnegie Hero Fund Commission, 2310 Oliver Bldg; h, 5545 Forbes St, Pittsburgh, Pa..**Mayflower 7300 and Atlantic 0954**

Holleran, Michael J. (Sept. 1929) Master Mechanic, Booth & Flinn Company, 1942 Forbes Street; h, 100 Baldwin Road, Pittsburgh, Pa. ....**Grant 0503**

Holliday, Alexander H. (**Associate Member**) (May 1914) Retired; h, 69 N. Harrison Ave, Bellevue, Pittsburgh, Pa...........**Linden 5700**

Holmes, Albert Bourne (March 1911) Asst. Supt, Safety, Welfare and Employment, National Works, National Tube Co; h, 1210 Park St, McKeesport, Pa.............................. **McKeesport 4144**

Holt, Harris B. (Jan. 1913) Sales Engr, Rosedale Fdy. & Mach. Co, Washington & Preble Ave, N. S; h, 1710 Montpelier St, Dormont, Pittsburgh, Pa.. **Cedar 4007**

Holveck, Joseph Emil (Sept. 1915) Vice President, The Aldrich Pump Co, Allentown, Pa; h, 2008 Crafton Blvd, Crafton, Pa.

Homer, William E. (Nov. 1923) District Sales Manager, Crane Packing Company, 99 Vandergrift Building; h, 278 Magnolia Avenue, Mt. Lebanon, Pittsburgh, Pa............................ **Court 2571**

Hook, C. Howard (Jan. 1925) Address Unknown.

★**Hopkins, Newton Fisher** (June 1903) Civil & Mining Engr, Harrop & Hopkins, 541 Wood St, Pittsburgh; h, 515 Hill Ave, Wilkinsburg, Pittsburgh, Pa.................................. **Atlantic 3824**

Hopwood, J. M. (May 1921) Pres, Hagan Corporation, Bowman Bldg; h, 2716 Espy Ave, Dormont, Pittsburgh, Pa.............. **Court 4724**

Hord, Peyton Robert (June 1920) Engr, W. Edgar Reed, 577 Union Trust Bldg; h, 713 Maryland Ave, Pittsburgh, Pa.......... **Atlantic 0478**

Horelick, Samuel (Associate) (April 1925) President, Pennsylvania Transformer Co, 2735 Railroad St; h, 1110 Cornell Ave, N. S, Pittsburgh, Pa.................................... **Atlantic 2078**

Horner, Ralph B. (Feb. 1924) Structural Engr, Pittsburgh Branch, Byllesby Engineering & Management Corp, 435 Sixth Ave, Pittsburgh; h, 527 Holmes St, Wilkinsburg, Pittsburgh, Pa......... **Grant 5750**

Hosler, Rush Norman (June 1903) Supt, Coal Mine Section, Pennsylvania Compensation Rating & Inspection Bureau, 210 N. 3rd St; h, 215 Paxtang Ave, Harrisburg, Pa.

Houssman, John (Jan. 1924) Machine Designer, United Engrg. & Fdry. Co, Farmers Bank Bldg, Pittsburgh, c/o W. D. McCartney, R. D. No. 2, Bridgeville, Pa.................................. **Atlantic 0863**

Hovey, O. W. (Associate Member) (June 1929) Bridge Designer, Penna. Dept. Highways, Harrisburg, Pa; h, 3203 N. 2nd St, Harrisburg, Pa.

Howell, Francis Kitchell (Oct. 1919) Sales Engr, Green Fuel Economizer Co, Beacon, N. Y; h, 94 Prospect St, Beacon, N. Y.

Howell, Sidney Albert (Oct. 1929) Pittsburgh District Manager, Carboloy Company, Inc, Grant Building, Pittsburgh, Pa; h, 600 S. Negley Avenue, Pittsburgh, Pa........................... **Atlantic 6853**

Hower, Harry S. (May 1915; Dec. 1925) Professor & Head, Dept. of Physics, Carnegie Institute of Technology; h, 5709 Solway St, Pittsburgh, Pa.. **Mayflower 2600**

Hubbard, Fred (June 1927) Cons. Engr, The Standard Slag Co, 1200 City Bank Bldg; h, 133 Halleck St, Youngstown, O.

Huff, George F. (Dec. 1927) Senior Mech. Engr, Byllesby Engrg. & Management Corp, 435 Sixth Ave; h, 6040 Bryant St, E. E. Pittsburgh, Pa. . . . . **Grant 5750**

Hufnagel, Frederick B. (Jan. 1907) Pres. Crucible Steel Co. of America, 2014 Oliver Bldg, Pittsburgh; h, Woodland Road & Irwin Drive, Sewickley, Pa. . . . . **Atlantic 3800**

Hufschmidt, Albert (March 1913) President, J. & J. B. Milholland Co, 714 Fifth Ave; h, 3520 California Ave, Pittsburgh, Pa. . . . . . **Grant 0223**

Hughes, I. Lamont (Sept. 1926) Vice President, United States Steel Corp, 71 Broadway, New York N.Y; h, 929 Park Avenue, New York N.Y.

Hulbert, Everson C. (Sept. 1916) Civil Engr, Crescent-Portland Cement Co; h, Wampum, Pa. . . . . **Wampum 80**

Hulse, Albert J. (Feb. 1929) Asst. Chief Engineer, H. A. Brassert & Co, 310 S. Michigan Ave; h, 7547 Cornell Ave, Chicago, Ill.

Hulse, S. C. (Sept. 1929) Bedford, Pa. **Bedford 63-W**

Hulst, John (Feb. 1917) V. P, United States Steel Corp, Room 1901, 71 Broadway; h, Hotel Pennsylvania, New York, N. Y.

★**HUMPHREY, ARTHUR L.** (**Gold Medal 1917**) (Feb. 1917) Pres, Westinghouse Air Brake Co, Wilmerding, Pa; h, 361 Maple Ave, Edgewood, Pittsburgh, Pa. . . . . **Brandywine 1490**

Hunt, Roy Arthur (May 1905) President, Aluminum Co. of America, 2400 Oliver Bldg; h, 4875 Ellsworth Ave, Pittsburgh, Pa. . . **Atlantic 4545**

Hunter, E. O. (**Associate Member**) (March 1929) Sales Represen ative, Biglow-Liptak Corp, 902 Union Bank Bldg; h, 1109 Downtown Y. M. C. A, Pittsburgh, Pa. . . . . **Court 0470**

★**HUNTER, JOHN A.** (**Silver Medal 1916**) (**Past President 1927**) (March 1903; April 1910) Asst. Chf. Engr, American Sheet & Tin Plate Co, Box 62, Frick Bldg, Pittsburgh, Pa; h, 151 Dickson Ave, Ben Avon, Pittsburgh, Pa. . . . . **Atlantic 1300**

Hunter, Percy E. (March 1896; April 1910) Pres, Independent Bridge Co, Neville Island, Pa; h, 836 N. Highland Ave, Pittsburgh, Pa. . . . . **Federal 3540**

★**Huntley, Louis Grow** (Oct. 1911) Partner, Huntley & Huntley, 505 Frick Bldg; h, 1333 Squirrel Hill Ave, Pittsburgh, Pa. . . . . . . **Atlantic 5615**

Hurn, John Sydney (**Associate**) (June 1924) Locomotive Engr, Union Railroad, Bessemer, East Pittsburgh, Pa; h, 1215 Uptegraf St, Swissvale, Pittsburgh, Pa. . . . . **Franklin 7208-J**

Hurtt, William Tisdale (Feb. 1925) Technical Mgr, United Oil Co, Preble & Franklin Ave, N. S. Pittsburgh; h, 503 Hill Ave, Wilkinsburg, Pittsburgh, Pa. . . . . **Cedar 1270**

Hutchinson, George Cass (March 1916) Dist. Representative, American Abrasive Metals Co, 1501 Farmers Bank Bldg, Pittsburgh; h, 245 Broad St, Sewickley, Pa. . . . . **Atlantic 0680**

★**Hutchinson, George Hunt** (Oct. 1880) (Oct. 1926) Engr, Davison Coke & Iron Co, Neville Island, Pa; h, 1100 Ridge Ave, Coraopolis, Pa. .... **Federal 3700**

Hutton, Frank E. (**Junior**) (Nov. 1929) Sales Agent, The Babcock & Wilcox Co, Koppers Bldg; h, 1520 S. Negley Avenue, Pittsburgh, Pa. .... **Atlantic 0672**

Iffarth, William C. (May 1919) Chief Engr, Harbison-Walker Refractories Co, 1800 Farmers Bank Bldg; h, King Edward Apts, Bayard St, Pittsburgh, Pa .... **Atlantic 0942**

Iiams, E. Jay (April 1921) Civil Engineer and Land Surveyor; h, 427 Fifth St, Donora, Pa .... **Donora 10-R**

Ingham, Frank (**Associate Member**) (Oct. 1928) Factory Representative, Baldwin Chain & Mfg. Co, Highland Bldg; h, 1132 Winterton St, Pittsburgh, Pa .... **Montrose 6281**

Ingram, Herschel Anthony (Dec. 1922) Sales Agent, The Babcock & Wilcox Co, 2730 Koppers Bldg; h, 341 S. Highland Ave, E. E. Pittsburgh, Pa .... **Atlantic 0672**

Irons, Dean M. (April 1925) Asst. Engr, Jones & Laughlin Steel Corp, 311 Ross St, Pittsburgh, Pa; h, 925 Vance Ave, Coraopolis, Pa .... **Court 3240**

Irvin, Richard (July 1910) Registered Architect & Engineer, Irvin Ramp Co, 99 Vandergrift Bldg; h, 213 Charles St, Knoxville, Pittsburgh, Pa .... **Court 2571**

Irvin, R. L. (March 1929) Metallurgist; h, 464 Arthur St, Gary, Ind.

Irvin, William A. (Dec. 1928) Vice President in Charge of Operations, American Sheet & Tin Plate Co; h, 901 N. Negley Ave, Pittsburgh, Pa .... **Atlantic 1300**

Iversen, Lorenz (June 1914) V. P, and Gen. Mgr, Mesta Machine Co, Box 1124; h, 5622 Bartlett St, Pittsburgh, Pa .... **Homestead 1080**

Jackman, David E. (**Associate**) (June 1912) Treas, Firth-Sterling Steel Co, McKeesport; h, 4924 Wallingford St, Pittsburgh, Pa .... **McKeesport 4181**

Jackson, John (Nov. 1910) V. P, The Simonds Mfg. Co, 25th & Liberty Ave; h, 11 Bascom St, N. S. Pittsburgh, Pa .... **Grant 0392**

Jackson, William (Jan. 1919) Engineer, American Bridge Co, Frick Bldg, Pittsburgh, Pa; h, 7417 Church Ave, Ben Avon, Pittsburgh, Pa. .... **Atlantic 4300**

Jackson, William H. (Feb. 1914) Pres, Pittsburgh-Des Moines Steel Co, Neville Island; h, Schenley Apts, Pittsburgh, Pa .... **Federal 3000**

Jacobs, Nathan B. (April 1921) Vice Pres, Morris Knowles Inc, 507 Westinghouse Bldg; h, 6329 Bartlett St, Pittsburgh, Pa .... **Atlantic 3882**

★**JAMES HENRY DuVALL** (**Past President 1922**) (Oct. 1902) Consulting Control Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 435 Locust St, Edgewood, Pittsburgh, Pa...**Brandywine 1500-Ext. 9369**

★**James, Joseph Hidy** (Jan. 1911) Professor of Chemistry, College of Engineering, Carnegie Inst. of Technology; h, 5868 Douglass Ave, Pittsburgh, Pa..................................**Mayflower 2600**

Jamison, William W. (Sept. 1893) V. P, Jamison Coal & Coke Co; h, 624 N. Main St, Greensburg, Pa....................**Greensburg 1980**

★**Jarvis, William Rice** (Feb. 1913) Dist. Mgr, Sullivan Machinery Co, 518 Farmers Bank Bldg; h, 307 S. Graham St, Pittsburgh, Pa...**Atlantic 2792**

Jayme, J. Phillip (July 1911) Crucible Steel Co. of America, Box 11, Grand Central Station, New York, N. Y.

Jefferies, Ernest (**Associate Member**) (Nov. 1927) Asst. Chief Draftsman, United States Aluminum Co, New Kensington, Pa; h, 519 Woodland Ave, Oakmont, Pa.

Jenkins, Raymond Rhys (May 1924) Sales Engr, General Electric Co, 1316 Oliver Bldg; h, 1118 Kelton Ave, South Hills Branch, Pittsburgh, Pa......................................**Atlantic 6400**

Jenks, Stephen Moore (May 1924) Fuel Engineer, American Sheet & Tin Plate Co, Gary Plant; h, 425 McKinley St, Gary, Ind.

Jett, Carter Coleman (April 1912; June 1916) Professor of Machine Design, University of Kentucky, Lexington, Ky; h, 368 Transylvania Park, Lexington, Ky.

Jobke, August F. (Jan. 1927) Asst. Power Engr, Bureau of Water, City of Pittsburgh, 309 City County Bldg; h, 135 Richey Ave, N. S. Pittsburgh, Pa............................**Atlantic 3900-204**

Johanson, Hjalmar K. (March 1927) Sales Engr, Electrical Paint & Varnish Co, Cleveland, O; h, 352 Kilbuck St, Glenfield, Pa.**Sewickley 1079-J**

Johns, Alexander Watson (May 1922) Borough Mgr, Borough of Ambridge; h, 931 Maplewood Ave, Ambridge, Pa......**Ambridge 35**

Johns, Thomas R. (June 1929) General Manager of Coal Mines, Bethlehem Mines Corporation, Johnstown, Pa; h, 146 Montour Avenue, (Westmont) Johnstown, Pa.

Johnson, Arthur B. (Feb. 1924) Sales Engr, Standard Steel Car Co, 1120 Frick Bldg; h, 10 Hemlock St, Mt. Lebanon, Pittsburgh, Pa...**Atlantic 1833**

★**Johnson, Charles Morris** (March 1919) Chief Chemist, Park Works, Crucible Steel Co. of America, 30th & Smallman Sts, Pittsburgh, Pa; h, 731 Orchard St, Avalon, Pittsburgh, Pa.................**Atlantic 3800**

Johnson, Edwin Howard (**Associate Member**) (March 1926) General Manager, Safety Mining Company, 307 N. Michigan Avenue, Chicago, Ill; h, 735 North Lombard Ave, Oak Park, Ill.

Johnson, Fred McCoy (**Associate Member**) (Oct. 1927) Sales Engr, Chapman-Stein Co; h, "Maple Lawn", Mt. Vernon, Ohio.

Johnson, J. A. (June 1928) 1518 E. La Rua St, Pensacola, Fla.

Johnson, John F. (June 1904; May 1914) Engineer, Pittsburgh Plate Glass Co, Grant Bldg, Pittsburgh, Pa.................... **Atlantic 5600**

Johnston, Edwin Van Deusen (Jan. 1905; Sept. 1913) Engineer; h, 1022 Portland St, Pittsburgh, Pa...................... **Montrose 0674**

★**Johnston, Howard L.** (April 1925) Director Industrial & Commercial Lighting, Duquesne Light Co, 435 Sixth Ave, Pittsburgh, Pa; h, 242 Avenue A, Wilkinsburg, Pittsburgh, Pa............... **Grant 4300**

Jones, Archibald (May 1921) Engineer, 709 Aiken Ave, Pittsburgh, Pa....................................... **Mayflower 0874**

Jones, Charles L. (Oct. 1927) Technical Director, Dry Ice Corp. of America, 52 Vanderbilt Ave, New York, N. Y; h, 54 Storer Ave, Pelham, N. Y.

Jones, David Guy (March 1924) Plant Engr, Pittsburgh Piping & Equipment Co, 43rd St. & A. V. R. R; h, 3340 Allendale St, Pittsburgh, Pa. .... **Fisk 1530**

Jones, Jonathan (Dec. 1924) Asst. Chief Engr, McClintic-Marshall Co, Box 1594, Pittsburgh; h, 816 Eleventh St, Oakmont, Pa...... .... **Atlantic 2562**

Jones, Marshall John H. (Sept. 1923) Gen. Mgr, Pennsylvania Division, (Mining Eng.) Bertha-Consumers Co, 1203 Chamber of Commerce Bldg; h, 5865 Alderson St, Pittsburgh, Pa............ **Atlantic 6920**

Jordan, Edward H. (March 1924) Chief Engr, H. J. Heinz Co, 1062 Progress St, N. S; h, 401 Wabana St, N. S. Pittsburgh, Pa........ **Cedar 5700**

★**Joy, Joseph F.** (Sept. 1921) Asst. to Vice President in Charge of Sales, Marion Steam Shovel Co, Marion, Ohio; h, P. O. Box 207, Marion, Ohio.

Kaiser, Benet Joseph (May 1921) Architect, 324-4th Ave; h, 521 Bellaire Ave, Pittsburgh, Pa................................ **Court 0965**

Kalbach, Wm. Robert (**Junior**) (Nov. 1928) Test Engr, Blaw-Knox Co, P. O. Box 915, Pittsburgh, Pa; h, East Liberty Y. M. C. A, Pittsburgh, Pa.................................... **Sterling 2700**

Karch, Herbert S. (June 1924) 281 Volga Way, Akron, Ohio.

Karn, Fred S. (May 1921) Sales Engr, Vacuum Oil Co, Clark Bldg, Pittsburgh, Pa; h, 518 Dickson Ave, Ben Avon, Pittsburgh, Pa...... .... **Atlantic 8370**

Karpov, Alexander V. (Dec. 1924) Designing Engr, Aluminum Co. of America, 2426 Oliver Bldg; h, 5643 Northumberland St, Pittsburgh, Pa.................................... **Atlantic 4545**

★**Kathner, Arthur T.** (June 1928) Representative Furnace Div, Duraloy Co, 26th and Sarah Sts, Pittsburgh, Pa; h, P. O. 357, New Cumberland, W. Va. . . . . **Hemlock 1154**

Katz, Sidney Hershberg (March 1927) Chemist in Charge, Gas Mask Laboratory, U. S. Bureau of Mines, c/o Safety in Mines, Research Board, Sheffield, England.

Keagy, Arthur D. (**Associate Member**) (Dec. 1925) Practicing Engr. & Contractor; h, 34 Altadena Drive, S. H. Sta, Pittsburgh. Pa. . . . . **Lehigh 1091**

Keebler, Homer J. (Nov. 1910; Nov. 1920) Engineer; h, 119 Meriden St, Mt. Washington Sta, Pittsburgh, Pa.

Keefer, George M. (Jan. 1907) Sales Mgr, Pittsburgh Branch, Rensselaer Valve Co, 937 Oliver Bldg; h, 446 Kenmont Ave, South Hills Station, Pittsburgh, Pa. . . . . **Atlantic 1636**

Keefer, William W. (Sept. 1903) Kehota Mining Co, First National Bank Bldg; h, 4302 Grant Blvd, Pittsburgh, Pa. . . . . **Atlantic 2311**

Keenan, Albert W. (May 1921) Construction Engr, Cooper Construction Co, Clymer, Indiana Cy, Pa; h, 509 S. Lang Ave, Pittsburgh, Pa. . . . . **Hiland 8393-W**

Keim, Byron L. (March 1923) Mech. Engr, Aluminum Co. of America, Eng. Dept, 205 Smithfield Bldg; h, 8001 Susquehanna St, Wilkinsburg, Pittsburgh, Pa. . . . . **Atlantic 4545**

★**Keller, Charles** (March 1895) Retired, 111 S. Lexington Ave, Pittsburgh, Pa. . . . . **Hiland 3541**

Keller, John Donald (Feb. 1928) Mechanical Engineer, Prof. Trinks, Carnegie Institute of Technology; h, 3308 Beechwood Blvd, Pittsburgh, Pa. . . . . **Mayflower 8946**

Keller, William Lloyd (Sept. 1910) Engr, The Koppers Construction Co, Koppers Bldg; h, 1239 Oakmont St, Crafton Sta, Pittsburgh, Pa. . . . . **Atlantic 6240**

Kelley, Henry D. (Feb. 1919) Dist. Mgr, Metal & Thermit Corp, 1514 North Ave, West, N. S. Pittsburgh, Pa. . . . . **Cedar 7987**

Kelly, Augustine B. (April 1927) Treas. & Genl. Mgr. Humphreys Coal & Coke Co, Box 52; h, 231 Westmoreland Ave, Greensburg, Pa. . . . . **Greensburg 7000**

Kelly, Joseph A. (March 1885) Pres. Reliance Steel Casting Co, 804 Federal Reserve Bldg; h, 5800 Wilkins Ave, Pittsburgh, Pa. . . . **Atlantic 5278**

Kelly, Joseph M., Jr. (May 1921) Hyatt Roller Bearing Co, 806 Fulton Bldg; h, 242 Dan Drive, Pittsburgh, Pa. . . . . **Atlantic 2927**

Kemery, Philo (March 1919) Chairman, Board of Directors, Pittsburgh Engrg, Fdry. & Const. Co, 39th St. & A.V.R.R; h, 341 Fisk St, Pittsburgh, Pa. . . . . **Fisk 3331**

Kendall, Theodore Herman (**Associate Member**) (Dec. 1925) Genl. Supt. of Distribution, Equitable Gas Co, 435 Sixth Avenue; h, 3130 Raleigh St, Dormont, Pittsburgh, Pa.........**Grant 7600-Line 49**

Kendall, Verner V. (May 1922) National Tube Co, Dept. of Metallurgy & Research, 1810 Frick Bldg; h, 3112 Pioneer Ave, Dormont, Pittsburgh, Pa....................................**Atlantic 2500**

Kenderdine, George (Jan. 1916) Asst. Engr, Pennsylvania Railroad Co, 654½ Main St, East Aurora, N. Y; h, 349 Oakland Ave, East Aurora, N. Y.

Kennedy, Joseph Walker (May 1923) Engr. with Julian Kennedy, 1217 Bessemer Bldg; h, 6401 Darlington Road, Pittsburgh, Pa.... ....**Atlantic 7730**

★**KENNEDY, JULIAN** (**Past President 1905**) (May 1886) Senior Partner, Julian Kennedy, Engr, Bessemer Bldg; h, 5400 Forbes St, Pittsburgh, Pa....................................**Atlantic 7730**

Kennedy, Julian, Jr. (June 1922) Julian Kennedy, Engr, 1217 Bessemer Bldg; h, 230 Thorn St, Sewickley, Pa..............**Atlantic 7730**

Kennedy, Louis P. (**Associate Member**) (May 1929) Sales Department, General Electric Company, 1314 Oliver Bldg; h, University Club, Pittsburgh, Pa.................................**Atlantic 6400**

Kenney, Frank M. (Oct. 1925) Engineer (Research) Duquesne Light Co, 435 Sixth Avenue; h, 129 Heathmore St, Brentwood, Pittsburgh, Pa......................................**Grant 3200-Ext. 328**

Keogh, Jere Kenney (**Associate Member**) (May 1921) Sales Repr, Allis-Chalmers Mfg. Co; 1209 Park Bldg; h, 240 Sieaforth Ave, Mt. Lebanon, Pittsburgh, Pa...........................**Atlantic 1729**

Kern, Paul Darlington (Nov. 1929) Engineer, American Tar Products Co, 1126 Koppers Bldg, Pittsburgh, Pa; h, 14 Evans Avenue, Ingram, Pittsburgh, Pa.........................**Atlantic 6240-Ext. 618**

Kerr, Andrew (Oct. 1902) Engr, McClintic Marshall Co, Oliver Bldg; h, 412 Locust St, Edgewood, Pittsburgh, Pa................**Atlantic 2562**

Kerr, Bert A. (April 1921) Engineer and Surveyor, Kerr & Martin, 611 Park Bldg; h, 1227 Wightman St, Pittsburgh, Pa...........**Atlantic 2165**

Khuen, Richard Jr. (May 1902) Gen. Mgr. Erection, American Bridge Co, Frick Bldg, Pittsburgh, Pa; h, Sewickley, Pa..........**Atlantic 4300**

Kiefer, Lewis J. (**Associate Member**) (June 1926) Superintendent, Farmers Natl. Bank Building, 301 Farmers Bank Bldg; h, 301 Perryview Avenue, N. S. Pittsburgh, Pa......................**Atlantic 0453**

Kier, Samuel Martin (Jan. 1909) Pres. The Kier Fire Brick Co, 1844 Oliver Bldg; h, Salina, Pa...............................**Atlantic 0957**

Kimmel, Charles Porter (Oct. 1915) Supt, Merchant Mills, Illinois Steel Co; h, 720 Jackson St, Gary, Ind.

King, Floyd E. (**Associate Member**) (June 1926) Illuminating Engr, Duquesne Light Co, 435-6th Ave, Pittsburgh; h, Box 317, Castle Shannon, Pa .... **Grant 4300-Ext. 215**

Kingsley, Charles Brown (Dec. 1929) Manager, Mississippi Glass Co, Floreffe, Pa; h, 438 Mitchell Ave, Clairton, Pa.

Kinter, Charles Willis (March 1926) Chf. Engr, Follansbee Brothers Co, h, 502 Mahan Ave, Follansbee, W. Va.

Kinter, Dean W. (**Junior**) (April 1927) Surveyor Class "C", Philadelphia Co, 435-6th Ave; h, 3340 Eastmont Ave, South Hills Branch P. O, Pittsburgh, Pa .... **Grant 4300-Ext. 551**

★**KINTNER, SAMUEL MONTGOMERY** (**Past President 1907**) (Jan. 1901) Head, Research Dept, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa. and Pres, International Devices Co, 1903 Farmers Bank Bldg; h, 1275 Beechwood Blvd, Pittsburgh, Pa .... **Brandywine 1500 and Atlantic 1364**

Kirk, David M. (**Associate**) (May 1912; Nov. 1929) h, P. O. Box 72, Sewickley, Pa.

Kirk, Ralph L. (Dec. 1926) Asst. to V. P, Duquesne Light Co, 435-6th Ave, Pittsburgh, Pa; h, 225 Laurel Ave, Ben Avon, Pittsburgh, Pa. .... **Grant 4300**

Kirker, Harry Lepper (Dec. 1909) Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 6734 Thomas St, Pittsburgh, Pa ..... **Brandywine 1500**

Kirkpatrick, George Myers (**Associate Member**) (Dec. 1922) Sales Engineer, Blaw Knox Company, P. O. Box 915; h. 1411 Mellon St, E. E, Pittsburgh, Pa .... **Sterling 2700**

Kiser, A. B. (June 1928) Genl. Supt, Mechanical Equipment, Pittsburgh Coal Co, 1021 Oliver Bldg; h, 52 Hawthorne Ave, Crafton, Pittsburgh, Pa .... **Atlantic 2181**

★**Klindworth, John Louis** (Feb. 1902) Asst. Chf. Engr, Aliquippa Works, Jones & Laughlin Steel Corp, Woodlawn, Pa; h, 1021 Vance Ave, Coraopolis, Pa .... **Aliquippa 101**

Kline, Robert Stevenson (July 1910) Draftsman, Jones & Laughlin Steel Corp, Aliquippa, Pa; h, 465 Dravo St, Beaver, Pa.

Knapp, James Howard (**Associate Member**) (March 1918) Asst. Supt, Open Hearth Dept, Duquesne Works, Carnegie Steel Co; h, 919 Kennedy Ave, Duquesne, Pa .... **Duquesne 5153**

★**Kneass, Strickland, Jr.** (Nov. 1914) Chief Engineer, A. M. Byers Company, Ambridge, Pa; h, 55 Thorn Street, Sewickley, Pa ..... **Atlantic 8110**

Kneeland, Herbert D. (Oct. 1913) Pres. and Treas, California Stucco Products Co, 1344 University Ave; h, 49 Wilshire Road, Brighton Station, Rochester, N. Y.

Knesche, Joseph Albert (April 1928) Mech. Engr, National Tube Co, Power Engine Dept, 1610 Frick Bldg; h, 6508 Jackson St, E. E, Pittsburgh, Pa.................................. **Atlantic 2500**

Knoble, Edward Frederick (Student Junior) (May 1927) Student, Carnegie Institute of Technology; h, 1245 Wisconsin Ave, Dormont, Pittsburgh, Pa.................................. **Lehigh 5021-R**

Knopf, Julius R. (Dec. 1920) Secretary, Director and Engineer, George J. Hagan Co, 1201 Chamber of Commerce Bldg, Pittsburgh, Pa; h, 1715 Montour St, Coraopolis, Pa.................. **Atlantic 8650**

Knotts, George Walter (April 1899) Dist. Mgr, United Engrg. & Fdry. Co, Youngstown District; h, 275 N. Heights Ave, Youngstown, O.

★**KNOWLES, MORRIS (Past President 1923) (Silver Medal 1920)** (March 1902) Pres. and Chief Engineer, Morris Knowles, Inc, 507 Westinghouse Bldg; h, 5814 Stanton Ave, Pittsburgh, Pa..... **Atlantic 3882**

Knox, Francis Henry (June 1891) Pres, Parr-Shoals Power Co. & Columbia Railway, Gas & Electric Co; h, Mt. Pleasant, S. C.

Koch, Carlton S. (June 1914) Pres, Fort Pitt Steel Casting Co, McKeesport, Pa; h, 623 Hampton Ave, Wilkinsburg, Pittsburgh, Pa.......... .... **McKeesport 5186**

Koch, Richard (Oct. 1926) V. P. & Technical Mgr, Concordia Electric Corp, 200 E. Ohio St; h, 1257 Denniston St, Pittsburgh, Pa.. **Fairfax 3822**

Koelkebeck, Carl (Junior) (Feb. 1925) Draftsman, Benwood Works, Wheeling Steel Corp, Benwood, W. Va; h, Bellview Heights, Bellaire, O.

Kohn, Roy E. (Associate Member) (Oct. 1926) Sales Engineer, Crane Co, Chicago, Ill; h, 1616 E. 46th St, East St. Louis, Ill.

Kolb, Frederick L. (Dec. 1929) Sales Engineer, Jeffrey Mfg. Co, 600 Second Avenue; h, 6379 Burchfield Avenue, Pittsburgh, Pa.... **Court 2926**

Kommer, J. Richard (April 1904) Consulting Engr, Box 1024, Pittsburgh, Pa.

Kramer, Frank P. (April 1921) Asst. to Dist. Engr, American Steel & Wire Co, 830 Frick Bldg; h, 3228 Perrysville Ave, N. S. Pittsburgh, Pa... **Atlantic 5720**

Kratzer, William N. (April 1903) W. N. Kratzer & Co, Struct. Iron Mfrs, 3212-3230 Smallman St, Pittsburgh; h, Glenfield, Pa..... **Grant 6490**

Kroske, Jacob Frederick (Associate Member) (Oct. 1926) Mgr, Pneumatic Tool Sales, Ingersoll-Rand Co, 706 Chamber of Commerce Bldg; h, 578 Peebles St, Wilkinsburg, Pittsburgh, Pa..... **Atlantic 9070**

Kroto, George (Oct. 1924) Dist. Mgr, National Transit Pump & Machine Co, 1421 Farmers Bank Bldg; h, 230 S. Euclid Ave, E. E. Pittsburgh, Pa. .... **Atlantic 1537**

Kruse, Alfred R. (Associate Member) (June 1922) Draftsman, United Engrg. & Fdry. Co, Farmers Bank Bldg; h, 142 Georgetown Ave, West View, Pittsburgh, Pa...................... **Atlantic 0863**

Kubitz, Fritz (Feb. 1917) Engr, 708 Publication Bldg, 209 Ninth St, Pittsburgh, Pa; h, Library, Pa, R. F. D. 1 .... **Atlantic 8059**

Kuhman, L. F. (March 1923) Manager, Tracyfier Dept, Blaw-Knox Co, P. O. Box 915, Pittsburgh, Pa; h, 138 Overlook Drive, Mt. Lebanon, Pittsburgh, Pa .... **Sterling 2700**

Kuntz, Joseph Franklin (Feb. 1903) Owner, The W. G. Wilkins Co, Engineers, 909 Westinghouse Bldg; h, 4352 Center Ave, Pittsburgh, Pa .... **Atlantic 4141**

★**LABOON, JOHN FRANCIS (Director)** (March 1923) Member of Firm, The J. N. Chester Engineers, 813 Clark Bldg; h, 346 Bower Hill Road, Mt. Lebanon, Pittsburgh, Pa .... **Atlantic 1140**

Lacock, J. S. (Associate Member) (Oct. 1927) Sales Engr. Mining Dept, General Electric Co, Oliver Bldg; h, 2231 Shady Ave, Pittsburgh, Pa .... **Atlantic 6400**

★**LADD, GEORGE TALLMAN (Past President 1927)** (Sept. 1902) President and General Manager, United Engineering & Foundry Company, 2307 Farmers Bank Building, Pittsburgh, Pa; h, R. D. No. 2, Box 46, Coraopolis Heights, Coraopolis, Pa .... **Atlantic 0863**

Lagatolla, Paul E. (Junior) (Oct. 1928) Jr. Assistant Engineer, Dept. of City Transit, City of Pittsburgh, 906 City-County Bldg; h, 6677 Woodwell Street, Pittsburgh, Pa .... **Atlantic 3900**

Lahr, Robert W. (March 1926) Draftsman, Phillips Mine & Mill Supply Co, 2227 Jane St, S. S; h, 3716 Evergreen Road, N. S, Pittsburgh, Pa .... **Hemlock 0130**

Laird, James B. (Associate Member) (Oct. 1929) Mfg. Agent, The Watson Stillman Co, Northern Engineering Works, The Canton Foundry & Machine Company, Union Trust Bldg; h, 238 Beverly Road, Mt. Lebanon, Pittsburgh, Pa .... **Atlantic 1535**

Lamb, Warren Vernon (Dec. 1927) Division Engr, Hillman Coal & Coke Co, Box 610, South Brownsville, Pa; h, P. O. Box 394, Brownsville, Pa.

Lamberger, Louis J. (Feb. 1925) Director, Power & Steam Sales, Duquesne Light Co, 435 Sixth Ave; h, 3325 Latonia Ave, Dormont, Pittsburgh, Pa .... **Grant 4300-211**

★**Lambie, Joseph Sioussa** (June 1923) Operating Manager, Concrete Products Co. of America, Diamond Bank Bldg; h, 1303 Singer Place, Wilkinsburg, Pittsburgh, Pa .... **Atlantic 3841**

Lamm, Lee L. (Jan. 1921) h, 6611 Watt Ave, Ben Avon, Pittsburgh, Pa. .... **Linden 2849-R**

Lanahan, Frank J. (Jan. 1921) Pres, Fort Pitt Malleable Iron Co, Box 492, Pittsburgh, Pa; h, 262 Dithridge St, Oakland, Pittsburgh, Pa. .... **Federal 1100**

Landahl, Eugene Everett (Oct. 1927) Construction Engineer, The Consolidation Coal Company, Fairmont, W. Va; h, 316 Gaston Ave, Fairmont, W. Va.

Lane, Harold (June 1922) Engineer, Wellman Seaver Morgan Company, Cleveland, Ohio; h, 1609 E. 94th Street, Cleveland, Ohio.

Langstaff, Harold A. P. (Nov. 1929) Electrical Engineer, West Penn Power Company, 14 Wood Street; h, 624 Ridgefield Avenue, South Hills P. O, Pittsburgh, Pa. . . . . **Court 4106**

Larned, James Murray (Jan. 1907) Engr. of Way, Pittsburgh Railways Co, 6th Floor, Duquesne Bldg; h, C-1 Alder Court Apts, Alder & Emerson Sts, Pittsburgh, Pa. . . . . **Grant 7450-Ext. 160**

Larson, Walter E. (Sept. 1927) Supt, Rees Mfg. Co, 7501 Thomas Blvd; h, 914 Milton St, Swissvale Br, Pittsburgh, Pa. . . . . . . **Hiland 5630**

Lassman, Benjamin (**Associate Member**) (Feb. 1929) Hydraulic Engineer, Oliver Bldg; h, 5857 Bartlett St, Pittsburgh, Pa. . . . . . **Atlantic 0932**

Latimer, George B. (**Associate Member**) (May 1926) Combustion Engineer; h, 286 Mercer Avenue, N. E, Warren, Ohio.

Lauer, Willard Wood (Dec. 1915) Construction Engr, Diamond Alkali Co; h, Painesville, Ohio.

Laughlin, Alexander (Feb. 1893) Alex. Laughlin & Co, First National Bank Bldg, Pittsburgh, Pa. . . . . **Atlantic 7600**

Laughner, William Edward, Jr. (Feb. 1925) General Drawing & Estimating, Private Practice, Ohio Valley Trust Bldg; h, 620 Chestnut St, Coraopolis, Pa. . . . . **Coraopolis 96**

Laverie, Marshall A. (**Junior**) (Feb. 1925) V. P, R. H. Laverie & Sons Inc, 17 State St, New York, N. Y; h, West Brighton, S. I, N. Y.

Lavine, Saul (Jan. 1925) Sales Engr, General Electric Co, 1314 Oliver Bldg; h, 6400 Bartlett St, Pittsburgh, Pa. . . . . **Atlantic 6400**

Lawlor, Richard C. (**Associate Member**) (April 1924) Sales Engr, The Anthony Co, 435 Wabash Bldg; h, 329 N. Craig St, Pittsburgh, Pa. . . . . **Court 0147**

Lawrence, Charles K. (Jan. 1899) Retired Chief Engineer, Central of Georgia Rwy; Executive and V. P, Equitable Bldg. & Loan Assoc, 16 W. Bryan St; h, 112J Victory Drive, Savannah, Ga.

Layng, Frank R. S. (June 1904) Asst. Chief Engineer, Bessemer & Lake Erie R. R, Greenville, Pa; h, 387 S. Main St, Greenville, Pa.

Leaf, James Pinney (Feb. 1899) Cons. Engr, 158 Brighton St; h, 290 West Park, Rochester, Pa. . . . . **Rochester 89**

Leathers, Harry M. (Dec. 1923) Dist. Mgr, The Dingle-Clark Co, 311 Ross St; h, 265 Parker Drive, Mt. Lebanon, Pittsburgh, Pa. . . . **Court 5778**

LeBon Charles Benoit (Nov. 1928) Chief Draftsman, Pittsburgh Coal Co. Shops, Library Pa; h, Library Pa. . . . . **Atlantic 2181**

LeCates, Raymond H. (**Junior**) (Feb. 1925) Tool Designer, Jones & Laughlin Steel Corp, 27th and Carson Streets, South Side; h, 240 Zara Street, Knoxville, Pittsburgh, Pa................ **Hemlock 0401**

Lee, Louis R. (Dec. 1927) Engr, Rust Engineering Co, Koppers Bldg, Pittsburgh, Pa.................................. **Atlantic 8870**

Leebov, Nathan (**Junior**) (March 1927) Architectural Engineer, 507 Jones Law Bldg; h, 306-C Saybrook Apts, Craft Avenue, Pittsburgh, Pa. .... **Court 4221**

Leeper, John B. (**Associate Member**) (Dec. 1923) Mgr, Tower Dept, American Bridge Co, 1431 Frick Bldg, Pittsburgh, Pa; h, Glenfield, Pa.. **Atlantic 4300**

Leet, Clifford S. (July 1911) Land Agent, Bessemer & Lake Erie R. R. Co, 689 Union Trust Bldg; h, 3110 Ashlyn St, Corliss Sta, Pittsburgh, Pa.. **Atlantic 4780**

Legg, Buell Bruce (March 1927) Engr, Columbia Engineering & Management Corp, 99 N. Front St, Columbus, Ohio, 849 Union Trust Bldg, Pittsburgh, Pa; h, 746 College Avenue, Columbus, Ohio. **Atlantic 9320**

Lehman, Albert C. (Jan. 1921) Pres, Blaw-Knox Co, P. O. Box 915; h, Schenley Apts, Pittsburgh, Pa...................... **Sterling 2700**

Lehman, George Mustin (June 1910) Engineer, River Front Improvement, Department of Public Works, City-County Bldg; h, Georgian Apts, Ellsworth Avenue, Pittsburgh, Pa........... **Atlantic 3900-Ext. 182**

Lehner, George Kriechbaum (April 1903) Partner, J. S. McIlvaine & Co, 406 Trust Co. Bldg, Chambersburg, Pa; h, 590 Montgomery Ave, Chambersburg, Pa.

Leichliter, Otto Gay (April 1927) Gen. Mgr, Reliance Coke & Furnace Co, 514 Frick Bldg, Pittsburgh; h, 1321 Singer Place, Wilkinsburg, Pittsburgh, Pa.................................. **Atlantic 1744**

Leinbach, Warren C. (Oct. 1924) Engr, Carnegie Steel Co, By-Product Coke Works, Clairton, Pa; h, 1642 Maplewood Ave, Wilkinsburg, Pittsburgh, Pa...................................... **Clairton 5**

Leisenring, William Jessup (**Associate Member**) (Nov. 1926) Salesman, American Locomotive Co, 617 Farmers Bank Bldg; h, Schenley Apts, Pittsburgh, Pa............................ **Atlantic 0789**

★**Leland, Edward D.** (Nov. 1904) Asst. to V. P, Equitable Gas Co, 435-6th Ave; h, 120 Ruskin Ave, Pittsburgh, Pa................ **Grant 7600**

Leonard, James Fulton (Oct. 1925) Engr. of Bridges & Buildings, Pennsylvania R. R, 1106 Pennsylvania Station, Pittsburgh, Pa; h, Glen Osborne, Sewickley, Pa......................... **Grant 6000-179**

Leonard, Raymond Davis (June 1929) Combustion Engineer, Pittsburgh Coal Company, Pittsburgh, Pa; h, 510 Hill Avenue, Wilkinsburg, Pittsburgh, Pa.................................. **Atlantic 2181**

★**LESHER, CARL EUGENE (Director)** (Dec. 1924) Executive V. P, Pittsburgh Coal Co, 1129 Oliver Bldg, Box 64, Pittsburgh; h, 247 Breading Ave, Ben Avon, Pittsburgh, Pa................. **Atlantic 2181**

Lewin, Francis Ashby Wake (Dec. 1926) District Manager, Coloder Company, Columbus, Ohio; h, 825 East End Ave, Wilkinsburg, Pittsburgh, Pa.................................... **Penhurst 1837**

Lewis, Essington (Feb. 1927) Managing Director, The Broken Hill Proprietary Co. Ltd, 422 Little Collins St, Melbourne, Australia; h, "Kooringa" Hamilton Ave, Malvern, Melbourne, Victoria, Australia.

★**LEWIS, HARRY J. (Past President 1899)** (May 1890) Cons. Engr, 336 Fourth Ave; h, 315 Maple Terrace, Pittsburgh, Pa.... **Court 1807**

Lewis, William H. (April 1907) Pres, Pennsylvania Engineering Works, New Castle, Pa; h, 1060 Devon Road, Pittsburgh, Pa.... **New Castle 307**

Lindquist, Otto B. (Oct. 1925) Consulting Engr, Allegheny Steel Co, Brackenridge, Pa; h, 1107 Park St, Tarentum, Pa.. **Tarentum 1000**

Lingle, Chester Munson (Feb. 1917) Vice President, The Buckeye Coal Co, Nemacolin, Greene County, Pa; h, 21 E. Berkley St, Uniontown, Pa.

Linn, Guy Fulton (Oct. 1922) Sales Engr, Representing Several Companies, 1503 Oliver Bldg, Pittsburgh, Pa; h, 1427 Elm St, Wilkinsburg, Pittsburgh, Pa.................................. **Atlantic 2820**

Little, Samuel Guy (Nov. 1928) Sales Engr, Penn Machine Co, 815 Berger Bldg; h, 425 Franklin Ave, Wilkinsburg, Pittsburgh, Pa...... .... **Court 2561**

Little, William Ross (April 1924) Mgr. Pittsburgh District, Fuller-Lehigh Co, 2730 Koppers Bldg; h, 4105 Aliquippa St, Pittsburgh, Pa. .... **Atlantic 0672**

Littler, Carl W. (June 1913) Chief Engr, Aliquippa Works, Jones & Laughlin Steel Corp, Aliquippa, Pa.................. **Aliquippa 101-Line 6**

Livermore, Arthur C. (Sept. 1920) V. P. and Gen. Mgr, Westinghouse Air Brake Home Building Co, Wilmerding, Pa; h, 223 Chestnut St, Edgewood, Pittsburgh, Pa.................... **Brandywine 1490**

Lloyd, Francis J., Jr. (Dec. 1928) Supt, The Dravo Contracting Co, 302 Penn Ave, Pittsburgh, Pa; h, 206 S. Water St, Kittanning, Pa. .... **Court 5400**

Lockhart, John Marshall (March 1917) 1508 Union Bank Bldg; h, 608 N. Highland Ave, Pittsburgh, Pa....................... **Court 1428**

Loeffler, George O. (April 1892; Jan. 1914) Sales Representative, Climax Molybdenum Company, 905 Union Trust Bldg; h, King Edward Apts, Pittsburgh, Pa.......................... **Atlantic 0622**

Loftus, Peter Francis (Oct. 1925) Cons. Electrical Engineer, Central Bldg, Brookville, Pa; h, 200 Deemer Place, Brookville, Pa.

Logan, Harold Milton (Sept. 1919) Chief Engineer and Pur. Agent, Hughes-Foulkrod Company, 421 Seventh Ave; h, 1136 Kelton Avenue, Dormont, Pittsburgh, Pa............................**Atlantic 7826**

Long, Clarence Edward (April 1921) Civil Engineer, Commonwealth Bldg. Annex, Pittsburgh; h, 601 Hill Ave, Wilkinsburg, Pittsburgh, Pa...**Court 1937**

Loomis, De Wayne (March 1894) 1st V. P. & Treas, H. L. Dixon Co, Carnegie, Pa; h, 29 S. Emily St, Crafton, Pittsburgh, Pa. **Walnut 0403**

Loomis, Franklin Wells (May 1927) Development & Illuminating Engr, Consolidated Lamp & Glass Co; h, 1210 Ridge Ave, Coraopolis, Pa...**Coraopolis 6**

Lose, James E. (May 1927) Supt. Carnegie Steel Co, Homestead Steel Works, Munhall, Pa; h, 1021 Savannah Ave, Swissvale, Pittsburgh, Pa.......................................**Homestead 2603**

Lougee, Lewis Omer (June 1925) Civil & Mining Engr, Geo. S. Baton & Co, 2413 First National Bank Bldg; h, 5723 Forbes St, Pittsburgh, Pa..................................**Atlantic 1576**

Loughin, Paul R. (**Associate Member**) (May 1929) Sales Agent, Babcock & Wilcox Co, 2730 Koppers Bldg; h, Apt. No. 8, 42 Academy Ave, Mt. Lebanon, Pittsburgh, Pa......................**Atlantic 0672**

Lovett, Sanford C. (**Associate Member**) (Dec. 1926) Sales Engineer, General Electric Co, 1318 Oliver Bldg; h, 1466 Alabama Avenue, Dormont, Pittsburgh, Pa.................................**Atlantic 6400**

Lower, N. M. (Dec. 1924) Lower Stoker Co, McPhail & Hollins St, Baltimore, Md; h, 2200 Garrison Blvd, Baltimore, Md.

Lowrie, William S. (May 1911) Supt. of Machine Shop, The Duraloy Co, New Cumberland, W. Va; h, 558 E. Main St, Ravenna, Ohio.

Lubelsky, Benjamin L. (**Associate Member**) (May 1929) Mining Engineer, Safety Mining Company, 307 N. Michigan Avenue, Chicago, Illinois; h, 1211 Savannah Avenue, Edgewood, Pittsburgh, Pa...**Penhurst 7877**

Ludgate, Bruce A. (July 1912; May 1919) Asst. Engr, P. & L. E. R. R, Terminal Bldg; h, Cathedral Mansions, Pittsburgh, Pa..**Court 3201**

Lundgren, Ernest H. (Jan. 1922) Construction Engr, Pennsylvania Dept, National Tube Co, 2222-2nd Ave; h, 626 Kirtland St, Homewood Sta, Pittsburgh, Pa..............................**Grant 1548**

Luty, Bertrand Elwood Vernon (Feb. 1899) Associate Editor, American Metal Market, New York City, 201 Bessemer Bldg, Pittsburgh, Pa; h, 3222 Perrysville Avenue, N. S, Pittsburgh, Pa....**Atlantic 6917**

Lynch, Clay F. (March 1924) V. P. & Gen. Mgr, H. C. Frick Coke Co, 110 Broadway, Scottdale, Pa; h, P. O. Box 62, Greensburg, Pa.

★**Lynch, Tillman D.** (Feb. 1898) Consulting Metallurgical Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 122 Washington Ave, Edgewood, Swissvale P. O., Pittsburgh, Pa. **Brandywine 1500**

Lynn, Frederick E. (May 1925) Refrigeration Engr, Suburban Electric Development Co, 5624 Penn Ave, Pittsburgh, Pa; h, 312 Moyhend St, Springdale, Pa.............................**Montrose 7200**

Lyon, Dugald (Feb. 1922) Mech. Engr, American Sheet & Tin Plate Co, Frick Bldg; h, 632 S. Negley Ave, Pittsburgh, Pa.....**Atlantic 1300**

Lyon, John A. (Junior) (Dec. 1927) Detailer, Pittsburgh Valve Fdry. & Const. Co, Pittsburgh, Pa; h, 1025 Evergreen Ave, Millvale, Pa... ....**Atlantic 6630**

McAleenan, George Robert (Nov. 1905) Pres, McAleenan Bros. Co, 25th & A. V. R. R; h. 1733 Beechwood Blvd,Pittsburgh, Pa **Atlantic 6540**

McBerty, Don R. (April 1929) Checker, Great Lakes Engineering Works, River Rouge, Mich; h, 2754 Pingree Avenue, Detroit, Michigan.

McBride, James Scott (Nov. 1904) Mech. Engr; h, 1601 Elbur Ave, Lakewood, Cleveland, Ohio.

McCabe, William Perry (Feb. 1914) Asst. Engr, Riter-Conley Works of the McClintic-Marshall Co, 332 Oliver Bldg. Pittsburgh, Pa; h. 1452 State Ave, Coraopolis, Pa.........................**Atlantic 2562**

McCain, Philip L. (Oct. 1925) Dist. Mgr, Louden Machinery Co, Grant Bldg; h, 283 Jefferson Drive, Mt. Lebanon, Pittsburgh, Pa...... ....**Grant 1120**

★**McCasland, Robert Wilson** (May 1909) Mining Engineer, Burbridge St. Germantown, Philadelphia, Pa.

McClane, William H. (May 1921) V. P, McClane Mining Co, 314 Washington Trust Bldg; h, R. D. No. 1, Washington, Pa.. **Washington 375**

McClintic, Howard Hale (Oct. 1892) V. P, McClintic-Marshall Co, 1201 Oliver Bldg; h, 1130 Beechwood Blvd, Pittsburgh, Pa.. **Atlantic 2562**

McClintock, Frank Stockton (Feb. 1910) Chief Engr, Dravo Doyle Co, 300 Penn Ave; h, 805 Amberson Ave, Pittsburgh, Pa........**Court 5400**

★**McCloy, Walter L.** (April 1923) Supt. Lease Dept, Ohio Fuel Gas Co, 99 N. Front St, Columbus, Ohio; h, 2618 Brentwood Road, Bexley, Columbus, Ohio.

★**McConnell, Malcolm Findley** (Nov. 1913) Supt, Carnegie Steel Co, Mingo Junction, O; h, 405 Belleview Blvd, Steubenville, O.

McConnell, Malcolm R. (Junior) (Nov. 1929) Power Engineer (Sales), West Penn Power Co, 14 Wood St; h, 210 N. Lang Avenue, Homewood, Pittsburgh, Pa.............................**Court 4106**

McCracken, Charles Kenneth (Associate Member) (Nov. 1928) Structural Engr, American Bridge Company, 1422 Frick Bldg, Pittsburgh, Pa; h, 722 Broad St, Sewickley, Pa....................**Atlantic 4300**

McCrystle, Jerome (March 1926) Supt, The Vesta Coal Co; h, 712 Fifth Ave, McKeesport, Pa........................**Brownsville 5016**

McCulloch, John A. (Associate Member) (March 1912) Engr, National Tube Co, 1020 First National Bank Bldg, Denver, Colorado.

★**McCullough, Frank M.** (Jan. 1911) Professor Civil Engineering, Carnegie Institute of Technology; h, 245 Melwood St, Pittsburgh, Pa..**Mayflower 2600**

McCune, Joseph C. (Dec. 1927) Asst. Director of Engineering, Westinghouse Air Brake Co, Wilmerding, Pa; h, 1432 Walnut St, Edgewood, Pittsburgh, Pa........................**Brandywine 1490**

McCune, William H. (May 1926) Asst. Metallurgical Engineer, American Sheet & Tin Plate Co, 1302 Frick Bldg; h, 5562 Hobart St, Squirrel Hill, Pittsburgh, Pa..............................**Atlantic 1300**

McDaniel, Bruce Penn (May 1921) V. P, Secy. and Sales Mgr, Power Piping Co, 829 Beaver Ave; h, 1442 Murray Ave, Pittsburgh, Pa. **Cedar 5664**

McDonald, Charles F. (Jan. 1900) Retired h, 116 S. Fifth St, Duquesne, Pa.

McDonald, Frank A. (March 1895) Gen. Supt. and Chf. Engr, National Mining Co, Morgan, Allegheny Co, Pa; h, 444 Beechwood Ave, Carnegie, Pa...............................**Bridgeville 245-J**

McDonald, Louis N. (Jan. 1900) Asst. Gen. Supt, Carnegie Steel Co; h, 239 Norwood Ave, Youngstown, O.

McDonald, Thomas M. (March 1893) Consulting Mgr, Youngstown Dist, Carnegie Steel Co, Box 4; h, 239 Norwood Ave, Youngstown, O.

McElheny, George B. (Associate) (Dec. 1926) Mechanical & Electrical Engr, Duquesne Light Co, 435-6th Ave; h, 1007 Heberton Ave, Pittsburgh, Pa...............................**Grant 4300-Ext. 342**

McEwen, Fred Bates (Oct. 1916) Pres, The Sommerville Co, 5641 Butler St; h, 560 Briarcliff Road, E. E. Pittsburgh, Pa..........**Fisk 0747**

McEwen, J. Allen (Dec. 1905) Vice Pres. & Chief Engr, Pittsburgh Bridge & Iron Works, 703 Fulton Bldg; h, 16 Castle Shannon Rd, S. Hills Sta, Pittsburgh, Pa........................**Atlantic 9250**

McEwen, J. D. (March 1922) Chief Engr, Lee C. Moore & Co, Inc, 624 Oliver Bldg; h, 212 Catalpa Place, S. H. Branch, Pittsburgh, Pa...**Atlantic 0808**

McFarlen, Joseph Pettis (Feb. 1926) Engrg. Dept, General Electric Co, 1316 Oliver Bldg; h, 53 Collins Ave, Pittsburgh, Pa.....**Atlantic 6400**

McGannon, Frank Edward (June 1926) Superintendent Construction, H. E. Culbertson Company, 1301 Clark Bldg; h, 99 Dewey Ave, Crafton, Pittsburgh, Pa...............................**Atlantic 0812**

McGarvey, Albert Gayton (May 1922) Chief Engr, The Pittsburgher Hotel, Diamond and Cherry Sts; h, R. F. D. No. 2, Bridgeville, Pa. ....**Atlantic 6970**

McGee, Frank Raymond (April 1911) Mech. Engr, Carnegie Steel Co, Mingo Junction, O; h, 1121 Oregon Ave, Steubenville, O.

McGinnis, Thomas Polk (**Associate Member**) (Nov. 1929) District Sales Representative, The Pyle-National Co, 420 Oliver Building; h, 147 Ridge Avenue, Ben Avon, Pittsburgh, Pa............ **Atlantic 0980**

McGonagle, Arthur (Sept. 1923) Consulting Engr, 1013 Fulton Bldg, Pittsburgh, Pa; h, 6815 Prospect Ave, Ben Avon, Pittsburgh, Pa.. **Atlantic 9688**

McGovern, Thomas J. (April 1921) Engr. for Carrick, Brentwood, Mt. Oliver, St. Clair and Hays Boroughs, 300 Brownsville Road; h, 2048 Brownsville Road, Mt. Oliver Sta, Pittsburgh, Pa.... **Lafayette 0109**

McGrath, Martin H, (**Associate**) (Dec. 1926) Electrical Engr, Standard Underground Cable Co, 17th & Pike Sts; h, 5454 Kincaid St, Pittsburgh, Pa.. **Grant 4580**

McGrew, Anson Burlingame (Dec. 192?) U. S. Assoc. Engr, U. S. Engineer Dept, 1662 Keenan Bldg, Pittsburgh, Pa; h, 259 Taylor Ave, Beaver, Pa.................................. **Atlantic 5958**

McIlvried, Howard George (March 1926) Asst. Chief Engineer, American Sheet & Tin Plate Company, Gary Tin Mill, Gary, Indiana.

McInerney, William I. (Dec. 1925) Supt, Heat Treating & Cold Drawing Depts, Pittsburgh Crucible Steel Co; h, 1133 Ohio Ave, Midland, Pa. .... **Midland 51**

McIntire, Thomas Brown (May 1913) Secy. & Treas, Middleman-McIntire Corp, 539-4th Ave; h, 350 S. Atlantic Ave, E. E. Pittsburgh, Pa. .... **Court 2667**

McIntosh, F. F. (Feb. 1911; Oct. 1925) Metallurgist, Crucible Steel Co. of America, 2014 Oliver Bldg, Pittsburgh; h, Glen Osborne, Sewickley, Pa .... **Atlantic 3800**

McIntyre, Lewis W. (Dec. 1927) Assoc. Prof. of Civil Engineering, University of Pittsburgh, Parkman & O'Hara Streets; h, 6630 Woodwell Street, Pittsburgh, Pa......................... **Mayflower 3500**

McKean, Robert A. (June 1910) Gen. Mgr, Riter-Conley Works of the McClintic-Marshall Co, 318 Oliver Bldg; h, 714 S. Negley Ave, Pittsburgh, Pa................................ **Atlantic 2562**

McKee, Frederick Chadwick (**Associate**) (Dec. 1926) V. P, West Penn Cement Co, 2215 Oliver Bldg; h, Webster Hall, Pittsburgh, Pa.... .... **Atlantic 2476**

McKee, Waldo McCutcheon (**Associate Member**) (Oct. 1927) Sales Mgr, The Tri-Lok Co, 5555 Butler St, Pittsburgh; h, 42 S. Freemont St, Bellevue, Pittsburgh, Pa........................... **Fisk 2750**

McKee, William Meek (Dec. 1916) Pres, W. M. McKee, Inc, Manufacturer's Agent, 436 Oliver Bldg; h, University Club, Pittsburgh, Pa. .... **Atlantic 4658**

McKenna, Roy Carnegie (Dec. 1928) President, Vanadium-Alloys Steel Co. Colonial Steel Company, Anchor Drawn Steel Company, McKenna Brass & Mfg. Company, 324 Fourth Avenue, Keystone Bldg; h, Box 236, Latrobe, Pa........................**Court 0582**

McKenzie, Charles Louis (Sept. 1903) President, Duquesne Slag Products Company, 808 Diamond Bank Bldg, Pittsburgh, Pa...**Atlantic 3841**

McKinley, Joseph (Dec. 1915) Mgr. Wholesale Sales & Service, Duquesne Light Co, 435 Sixth Ave; h, 940 Farragut St, Pittsburgh, Pa. ....**Grant 4300**

McKinney, Robert Marshall (April 1921) Civil & Mining Engr, Dravosburg, Pa...**McKeesport 7732**

McKown, Harry E. (**Associate Member**) (March 1925) Draftsman, Spang-Chalfant & Co, Inc, Etna, Pa; h, 6th St. & Maple Ave, Aspinwall, Pittsburgh, Pa...................................**Sterling 0740**

McKown, Howard Purcell (Feb. 1927) President, J. Toner Barr Co, 1600 Princess Street; h, 219 Princeton Avenue, West View, Pittsburgh, Pa...**Lehigh 4500**

McLean, Harold Alfred (**Associate Member**) (April 1927) President W. B. McLean Mfg. Co, 729 Herron Ave; h, 6755 McPherson Blvd, Pittsburgh, Pa...................................**Schenley 4005**

McLOUGHLIN, THOMAS J. (**Director**) (March 1919) Fuel Engr, Carnegie Steel Co; h, 706 Crawford St, Duquesne, Pa..**Duquesne 5153**

McMichaels, W. A. (Nov. 1924) Engr, 381 Second St, Pitcairn, Pa,

McMillen, Albert Knox (May 1912) Chf. Engr, Alex. Laughlin & Co. Engineers & Contractors, 1802 First National Bank Bldg; h, 2764 S. Bergman St, Pittsburgh, Pa........................**Atlantic 7600**

McMillen, Russell H. (June 1918) Metallurgist, La Belle Works, Crucible Steel Co. of America, Ridge Ave. & Reedsdale St; h, 1115 King Ave, Pittsburgh, Pa...................................**Atlantic 3800**

McMillin, O. B. (April 1922) Metallurgist, Pittsburgh Rolls Corp, 41st and Willow Sts; h, 7534 Bennett St, Pittsburgh, Pa...........**Fisk 2490**

McMullen, Philip S. (April 1921) Civil Engr. and Land Surveyor, Official Borough Engr, Glassport; h, Pacific & Summit Aves, Glassport, Pa..**Glassport 1-M**

★**McNaugher, David White** (Dec. 1896) V. P. & Treas. Robert W. Hunt Co, Professional Bldg, 429 Penn Avenue; h, 2301 Osgood Street, Pittsburgh, Pa...**Atlantic 3950**

McNeil, Donald (Jan. 1909) Pres, The Donald McNeil Co, Winebiddle Ave. & P. R. R; h, 455 S. Atlantic Ave, Pittsburgh, Pa...... ....**Montrose 5715**

McNiff, Gilbert P. (June 1917) Asst. V. P, National Tube Co, 1711 Frick Bldg, Box 132; h, 5826 Marlborough St, Pittsburgh, Pa.**Atlantic 2500**

McQuiston, William Bryce (Nov. 1925) Salesman, Kier Fire Brick Co, 1844 Oliver Bldg; h, 606 Hampton Ave, Wilkinsburg, Pittsburgh, Pa..**Atlantic 0957**

McRoberts, William H. (**Associate Member**) (June 1924) Chief of Survey Corps, State Dept. of Highways, 55 Water St, Pittsburgh, Pa; h, 538 Dawson Ave, Bellevue, Pittsburgh, Pa.........**Court 4150**

McWade, Frank J. (Jan. 1926) Supervising Engineer, Real Estate Department, Firestone Tire & Rubber Company, Akron, Ohio; h, 1257 Wisconsin Ave, Dormont, Pittsburgh, Pa ....**Lehigh 1588-R**

Macartney, John William (**Associate**) (June 1910) Salesman, Cooper-Bessemer Corp, 50 Church Street, New York; h, 268 Prospect Street, East Orange, N. J.

MacDonald, Rowland (October 1929) Mechanical Engineer, Westinghouse Elec. & Manufacturing Co, Page Blvd, Springfield, Mass; h, 9 Pelham Street, Worcester, Mass.

★**Macfarren, Walter W.** (Nov. 1907; Nov. 1925) Mechanical Engineer, 401 Maryland Ave, Oakmont, Pa....................**Oakmont 299-J**

MacGaugh, Myles C. (**Junior**) (June 1929) Jr. Assistant, City of Pittsburgh, Department of City Transit, 906 City-County Building, Pittsburgh, Pa; h, 530 Pennsylvania Avenue, Oakmont, Pa......**Atlantic 3900**

MacGregor, John R. (**Associate Member**) (Dec. 1928) Chief Engineer, Bell Telephone Co. of Penna, 416 Seventh Ave; h, 453 Dawson Avenue, Bellevue, Pittsburgh, Pa..................**Official 0050**

Mackenzie, James J. P. (**Junior**) (Feb. 1929) Sales Engineer, Walworth Company, Greensburg, Pa; h, Webster Hall, Pittsburgh, Pa...... ....**Mayflower 7700**

MacLachlan, Robert (Feb. 1929) Superintendent, Champion No. 3 Preparation Plant, Research Division, Pittsburgh Coal Company, Library, Pa; h, R. D. No. 1, Library, Pa.....................**Library 52**

Magill, Franklin R. (March 1924) Sales Engineer, The Dingle-Clark Co, Room 306, 311 Ross Street; h, 509 Lyndhurst Avenue, S. H. Branch, Pittsburgh, Pa..............................**Court 5778**

Magnani, Charles (Sept. 1924) Asst. to Engineer, Power Investigating Committee, U. S. Steel Corp, 426 Frick Bldg, Box 132; h 1208 Kelton Ave, Dormont, Pittsburgh, Pa ....**Atlantic 2504**

Maher, Thomas Delaney (**Associate Member**) (March 1927) Industrial Lighting, Duquesne Light Co, 435 Sixth Ave, Pittsburgh, Pa; h, Apt. 9, New Hunter Bldg, Wilkinsburg, Pittsburgh, Pa...... ....**Grant 4300-Line 209**

Malady, John A. (April 1925) Mech. & Elec. Engr, Hillman Coal & Coke Co, 2307 First National Bank Bldg; h, 46 Stewart Ave, Carrick, Pittsburgh, Pa.........................**Atlantic 2620**

Malevich, Vladimir (Dec. 1925) Structural Engr, Jones & Laughlin Steel Corp, 3450-2nd Ave; h, 344 Becks Run Road, Pittsburgh, Pa.. .... **Atlantic 9670**

Mali, Franklin F. (May 1922) Works Engineer, National Electric Products Corp, National Metal Molding Division, Ambridge, Pa; h, 801 Sixth Street, New Brighton, Pa.................... **Ambridge 15**

Malmstrom, Uno W. (May 1911) Chief. Engr, J. A. Roebling's Sons Co. 612 S. Broad St, Trenton, N. J; h, 853 Highland Ave, Morrisville, Pa.

Malseed, William H. (**Associate Member**) (Dec. 1925) Supt, Cuthbert Bros, Co, Bessemer Bldg, Pittsburgh; h, 409 Windsor St, McKeesport, Pa... **Grant 5736**

★**MANDEVILLE, J. BRADLEY** (**Silver Medal 1921**) (June 1916) Purchasing Agent, Consolidated Gas Utilities Company, First National Bank Building, Oklahoma City, Okla.

Manley, C. Reynolds (**Junior**) (Feb. 1925) Plant Engineer, National Lead and Oil Company of Pa, New Kensington, Pa; h, 1717 Ridge Ave, New Kensington, Pa.

Mann, Harvey B. (April 1924) V. P, Dravo-Doyle Co, Dravo Bldg, 300 Penn Ave, Pittsburgh, Pa; h, 7302 Brighton Road, Ben Avon, Pittsburgh, Pa... **Court 5400**

Mansfield, Myron G. (**Associate Member**) (April 1926) Division Engr. & Secy, Morris Knowles, Inc, 507 Westinghouse Bldg; h, 7046 Penn Ave, Pittsburgh, Pa............................ **Atlantic 3882**

Mantle, Gregory Douglass (March 1923) Pres, Mantle Engineering Co, Oliver Bldg; h, 5738 Kentucky Ave, Pittsburgh, Pa.... **Atlantic 0338**

Marks, Herbert E. (**Associate**) (Oct. 1914) President, H. E. Marks Corporation, First National Bank Bldg, McKees Rocks, Pa; h, Orchard and Linden Sts, Glen Osborne, Sewickley, Pa......... **Federal 3608**

Marsh, Burton Wallace (June 1926) Traffic Engr, City of Pittsburgh, 908 City-County Bldg; h, 1031 Norwich Ave, Pittsburgh, Pa....... .... **Atlantic 3900-Ext. 283**

Marshall, Charles D. (May 1896) Pres, McClintic-Marshall Co, 1217 Oliver Bldg; h, 6300 Fifth Ave, Pittsburgh, Pa............. **Atlantic 2562**

Martin, Charles A. (Oct. 1921) Engr. & Surveyor, Kerr & Martin, 611 Park Bldg; Pittsburgh, Pa; h, 1450 Ridge Ave, Coraopolis, Pa. **Atlantic 2165**

Martin, George F., Jr. (**Student Junior**) (Oct. 1927) Student, Carnegie Institute of Technology, also with Dr. V. N. Krivobok, Met. Research Bureau, Pittsburgh; h, 802 Ross Avenue, Wilkinsburg, Pittsburgh, Pa................................ **Churchill 3800**

★**MARTIN, JAMES STEWART** (**Silver Medals 1918-1922**) (March 1913) Chief Structural Engr, Walter Bates Steel Corp; h, 470 Hayes St, Gary, Ind.

Martin, John M. (Jan. 1903) Mgr. Shiffler Plant, American Bridge Co, 115 51st St; h, 5396 Wilkins Ave, Pittsburgh, Pa. . . . . **Atlantic 4300**

Martin, Park H. (April 1921) Pres, McBride Surveying & Engrg. Co Ltd, 331-4th Ave, Pittsburgh, Pa; h, 44 N. Howard Ave, Bellevue, Pittsburgh, Pa. . . . . **Court 1787**

Mason, E. J. (Jan. 1903) Asst. Engr, Heyl & Patterson, Inc, 50 Water St, Pittsburgh; h, 56 Taylor St, Crafton, Pittsburgh, Pa. **Court 0753**

Mason, J. Robert (**Associate Member**) (Jan. 1914) Dist. Sales Engr, The Wickes Boiler Co, 1218 Empire Bldg; h, 3240 Beechwood Blvd, Pittsburgh, Pa. . . . . **Grant 8294**

Masters, William C. (April 1920) Sales Engineer, Pittsburgh Screw & Bolt Company, Pittsburgh, Pa; h, 1046 Vance Ave, Coraopolis, Pa. . . . . **Linden 5300**

Matheson, Charles P. (April 1921) V. P. & Treas, Pittsburgh Building Specialties Co, 1105 Jones Law Bldg; h, 660 Maryland Ave, Pittsburgh, Pa. . . . . **Court 4296**

Mathieu, Henry Philip (**Associate Member**) (Nov. 1928) Sales Engineer, Dravo-Doyle Company, 300 Penn Ave, Pittsburgh, Pa; h, 902 Forrest Avenue, Ross Township, Pittsburgh, Pa . . . . . **Court 5400**

Mattingley, George B. (**Associate Member**) (May 1924) Dist. Sales Mgr. Edge Moor Iron Co, Edge Moor, Delaware; h, 1504 Delaware Ave, Wilmington, Del.

Mauser, Louis K. (**Associate Member**) (Nov. 1926) Commercial Development, 908 Mahoning Bank Bldg; h, 174 W. Glenaven Ave, Youngstown, O.

Mayer, Raoul G. (Dec. 1927) Designer, National Tube Company, McKeesport, Pa; h, 1436 Elm Street, Wilkinsburg, Pittsburgh, Pa . . . . . **McKeesport 4144**

Mechesney, Charles Alexander (Jan. 1924) Engr, Equitable Gas Co. and Pittsburgh & West Virginia Gas Co, 435-6th Ave, Pittsburgh, Pa; h, 404 Center St, Wilkinsburg, Pittsburgh, Pa . . . . **Grant 7600-Ext. 40**

Medley, Harold C. (**Associate Member**) (June 1923) Draftsman, Heyl & Patterson, Inc, 50 Water St; h, 227 Spencer Ave, Carrick, Pittsburgh, Pa . . . . . **Court 0753**

Meermans, Leonard H. (**Junior**) (Nov. 1929) Cadet Engineer, Equitable Gas Company, 435 Sixth Avenue, Pittsburgh, Pa; h, 4 Buffalo St, Pittsburgh, Pa. . . . . **Grant 7600**

Meharg, Laurence (June 1924) h, Beech Glen, Wheeling, W. Va.

Mekeel, David Lane (Feb. 1901) Chief Engr, Jones & Laughlin Steel Corp, 315 J & L Bldg, Pittsburgh, Pa; h, Coraopolis, Pa . . . . . **Court 3240**

Melat, Homer B. (**Associate**) (Jan. 1910) Civil Engr. and County Surveyor; h, Kennerdell, Pa.

Melcher, John P. (Sept. 1924) Pittsburgh Valve, Fdry. & Const. Co, P. O. Box 1016; h, 263A Gross St, Pittsburgh, Pa.... **Atlantic 6630**

Mellsop, Clifton E. (May 1910) Engineer, Riter-Conley Works of the McClintic-Marshall Co, 1207 Oliver Bldg; h, 7462 Pennfield Place, Pittsburgh, Pa.................................. **Atlantic 2562**

Menaglia, V. A. (March 1929) Sales Engineer, S. K. F. Industries, 923 Grant Bldg; h, 7125 McPherson Blvd, Pittsburgh, Pa.. **Atlantic 7440**

Merrill, Ferrand Seymour (Nov. 1926) Asst. to Div. Engr, American Bridge Company, 1422 Frick Bldg, Pittsburgh; h, 509 Glen Mitchell Road, Sewickley, Pa.................................. **Atlantic 4300**

Messler, Eugene L. (Jan. 1901) Pres, Eureka Fire Brick Works, 1507 First National Bank Bldg; h, 5423 Forbes St, Pittsburgh, Pa.... .... **Atlantic 0643**

Metzger, William F. (**Associate Member**) (Dec. 1926) V. P, H. O. Swoboda, Inc, 3400 Forbes St; h, 1502 Hetzel St, N. S, Pittsburgh, Pa...... .... **Mayflower 8356**

Meyer, Paul Abner (Sept. 1905) Supt. Track & Roadway, West Penn Railways Co, Connellsville, Pa; h, 413 W. Third St, Greensburg, Pa.

Meyran, Louis A. (Jan. 1884) V. P, Manufacturers Light & Heat Co, Union Bank Bldg; h, 1125 Shady Avenue, Pittsburgh, Pa...... **Court 1311**

Middleton, Raymond T. (**Associate Member**) (May 1925) Contracting Engr, Roberts and Schaefer Co, 417 Oliver Bldg; h, 5329 Beeler St, Pittsburgh, Pa.................................. **Atlantic 4881**

Mikaloff, John P. Jr. (Nov. 1926) Asst. Fuel Engr, Carnegie Steel Co; h, 220 W. Oliver Ave, Duquesne, Pa................ **Duquesne 5153**

Millar, Robert John (May 1915) Registered Architect; h, 316 Dalzell Ave, Ben Avon, Pittsburgh, Pa..................... **Linden 3278-R**

Millard, Emmor Hamilton (Jan. 1924) President, Steel Frame House Co, Oliver Bldg, Pittsburgh; h, 213 Chestnut Road, Edgeworth, Sewickley, Pa.................................. **Atlantic 2562**

Miller, Cyrus E. (April 1921) Civil Engr, 5147 Jenkins Arcade Bldg, Pittsburgh, Pa; h, 147 Grant Ave, Bellevue, Pittsburgh, Pa.. **Atlantic 9065**

Miller, Harry Rhodes (Jan. 1923) Chief Engr, Pittsburgh Coal Co, 1012 Oliver Bldg, Pittsburgh; h, Elizabeth, Pa....... **Atlantic 2181**

Miller, Henry Barron (May 1923) Retired Mining Engr; h, 35 Hilaire Road, St. Davids, Delaware Co, Pa.

Miller, James M. (May 1923) Production Manager, Penn Electrical Co, Irwin Pa; h, 14 First St, North Irwin, Pa............... **Irwin 83**

Miller, John F. (Feb. 1921) Vice Chairman, Westinghouse Air Brake Co, Wilmerding, Pa; h, 222 Hawthorne St, Edgewood, Pittsburgh, Pa. .... **Brandywine 1490**

Miller, Joseph Torrence (Jan. 1903; May 1926) Secy-Treas. & P. A, Pennsylvania Water Co, 712 South Ave, Wilkinsburg, Pa; h, 424 Maple Ave, Edgewood, Pittsburgh, Pa.................. **Penhurst 0910**

Miller, Lyman H. (March 1925) Asst. Supt, American Steel & Wire Co, Braddock, Pa; h, 549 S. Braddock Ave, Pittsburgh, Pa.......... .... **Brandywine 3350**

Miller, William Booth (Dec. 1899) Pres. & Treas, Pihl & Miller, Contracting Engineers, Wabash Bldg, Pittsburgh, Pa; h, 520 Pine Road, Sewickley, Pa.................................. **Court 1670**

Milliken, James (Dec. 1919) Pres. Pittsburgh Testing Laboratory, Stevenson & Locust Sts, P. O. Box 1115; h, 4914 Center Ave, Pittsburgh, Pa.. **Grant 3860**

★**Mills, Charles Peale** (Oct. 1927) Chief Engr, The Duraloy Co, 26th and Sarah Sts; h, 5663 Beacon St, Pittsburgh, Pa..... **Hemlock 1154**

Milton A. Loring (June 1922; Oct. 1925) Mech. Engr, Wheeling Steel Corp. Benwood, W. Va; h, 16 Echo Terrace Ave, Wheeling, W. Va.

Miner, Philip H. (**Associate Member**) (Oct. 1924) Chief Engr, Tracyfier Dept, Blaw-Knox Co, Blaw-Knox, Pa; h, 614 Forest Ave, Bellevue, Pittsburgh, Pa................................ **Sterling 2700**

Minnotte, Joseph F. (April 1929) Secy.-Treas, Minnotte Brothers Co, Inc, 906 House Bldg; h, 371 Orchard Drive, Mt. Lebanon, Pittsburgh, Pa.. **Court 0514**

Mirick, Alfred S. (**Associate Member**) (Dec. 1924) Engr; h, 5456 Penn Ave, Pittsburgh, Pa............................ **Hiland 0118-J**

Mitchell, Robert A. (Feb. 1924) Engineer, Link Belt Co, 2125 Koppers Bldg; h, Pittsburgh Athletic Assn, Pittsburgh, Pa.... **Atlantic 1692**

Mitchell, Thomas J. (June 1924) Crescent Brick Co, 807 Empire Bldg; h, 1617 Falk Ave, N. S, Pittsburgh, Pa................ **Atlantic 7820**

Moeller, Nils D. (Oct. 1924) Mech. Engr, The Koppers Co, Koppers Bldg; h, 1510 Hillsdale Avenue, Dormont, Pittsburgh, Pa...... .... **Atlantic 6240**

Monk, P. S. (Feb. 1924) h, 1219 Morningside Ave, Pittsburgh, Pa....... .... **Hiland 2674-R**

Monro, William L. (Jan. 1921) Pres. & Gen. Mgr, American Window Glass Co, Farmers Bank Bldg; h, 5840 Wilkins Ave, Pittsburgh, Pa.... .... **Atlantic 0449**

Moore, Emmett Hayden (**Associate Member**) (Feb. 1925) Senior Draftsman, Allegheny County, 519 Smithfield Street, Room 205; h, 101 Emerson Ave, Aspinwall, Pittsburgh, Pa...... **Atlantic 4900-Line 44**

Moore, H. Lee (Oct. 1918) Mgr, Pittsburgh Office, Buffalo Forge Co, 927 Union Trust Bldg, Pittsburgh, Pa; h, 7065 Flaccus Road, Ben Avon, Pittsburgh, Pa.......................... **Atlantic 3581**

Moore, Lee C. (Jan 1906; Sept. 1924) Lee C. Moore & Co, 612 Philtower Life Bldg, Tulsa, Okla; h, 1113 Sunset Drive, Tulsa, Okla.

Moore, Ralph Waldo Emerson (Oct. 1927) Engineering Mgr, Association Activities, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, Cathedral Mansions, Ellsworth Ave, Pittsburgh, Pa.......... **Brandywine 1500**

★**Moore, William E.** (June 1918) Pres. W. E. Moore & Co, P. O. Box 1125, 32nd St. & Allegheny River; h, 368 S. Evaline Street, Pittsburgh, Pa.......... **Grant 6221**

Moreland, William C. (Jan. 1904) V. P, Jones & Laughlin Steel Corp, J. & L. Bldg, Pittsburgh, Pa; h, Coraopolis Heights, Coraopolis, Pa. .... **Court 3240**

Morgan, Edward F. (Feb. 1924) Partner, E. F. Morgan Co, 1517 Clark Bldg, Pittsburgh; h, R. D. No. 1, Allison Park, Pa.... **Atlantic 1565**

Morganstern, Ralph M. (June 1902) Owner, Morganstern Electric Co, 334-2nd Ave; h, 5421 Maynard St, Pittsburgh, Pa....... **Court 1106**

Morgenstern, W. C. (Oct. 1924) Sales Engr, Steam Equipment Mfg. Co 428 Jenkins Arcade; h, 308 Dunlap Ave, Pittsburgh, Pa. **Atlantic 6509**

Morison, George Smith (June 1924) Pres. & Engr, Morison Incorporated, 246 Third Ave; h, Loutellus Apts, 245 Melwood Ave, Pittsburgh, Pa.......... **Court 2675**

Morris, Alfred A. (Oct. 1924) Lubrication Engr, Gulf Refining Co, Gross St. & P. R. R, Pittsburgh, Pa; h, 313 Penwood Ave, Wilkinsburg, Pittsburgh, Pa.......... **Schenley 1000**

Morrison, George W. (Feb. 1924) District Manager ,Vanadium Alloys Steel Company, 240 Plainfield Street, Springfield, Mass; h, 70 Leyfred Terrace, Springfield, Mass.

Morrison, Thomas (April 1893) Retired, Highland Bldg, E. E; h, 1400 N. Highland Ave, Pittsburgh, Pa.......... **Montrose 8104**

★**MORSE, EDWIN KIRTLAND (Past President 1910)** (Jan. 1896) Consulting Engineer, Private Practice, 345-4th Ave; h, 255 N. Craig St, Pittsburgh, Pa.......... **Court 0170**

Morse, George H. (March 1927) Gen. Supt, Northern Coal Mines, Republic Iron & Steel Co, 1743 Oliver Bldg; h, 1338 Sheridan Ave, Pittsburgh, Pa.......... **Atlantic 2253**

Morton, William Alfred (May 1922) Pres, Amsler-Morton Co, Inc, 720 Fulton Bldg; h, 1512 Westfield St, Beechview, Pittsburgh, Pa. . **Atlantic 8735**

Moses, Graham Lee (Associate) (Oct. 1925) Electrical Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 409 West St, Wilkinsburg, Pittsburgh, Pa.......... **Brandywine 1500-Ext. 9147**

Motok, George Thomas (Student Junior) (Oct. 1926) Student in Metallurgy, Carnegie Institute of Technology; h, Box 330, Carnegie Institute of Technology, Pittsburgh, Pa.......... **Mayflower 2600**

Mott, William Elton (April 1910) Director, College of Engineering, Carnegie Institute of Technology, Schenley Park; h, 58 King Edward Apts, 4609 Bayard St, Pittsburgh, Pa.................... **Mayflower 2600**

Mulert, Justus Louis (**Associate Member**) (June 1928) Engineering Asst. Bell Telephone Co. of Pa, 2756 W. Liberty Ave, S. H. Branch; Pittsburgh, Pa; h, 842 Washington Rd, South Hills, Pittsburgh, Pa. .... **Official 0050-Ext. 225**

Mullen, John L. (April 1906) Pres, John L. Mullen Construction Co, 602 Wabash Bldg; h, 2756 S. Bergman St, Pittsburgh, Pa... **Court 2186**

Mundo, Charles Joseph (Dec. 1926) Dist. Repr, Monitor Controller Company, Ohio Electric & Controller Company, 241 Union Trust Bldg; h, 5532 Hobart St, Pittsburgh, Pa................. **Atlantic 4592**

Murray, John J. (March 1921) Div. Supt, Equitable Gas Co, 6119 Penn Ave, E. E; h, 804 S. Millvale Ave, Pittsburgh, Pa...... **Hiland 6700**

Murto, Harry Charles, Jr. (**Associate Member**) (Nov. 1925) Salesman, Hillside Stone & Supply Co, P. O. Box 1753; h, 232 Hastings St, Pittsburgh, Pa.................................. **Sterling 0800**

Mylrea, Thomas Douglas (Jan. 1929) Professor, Building Construction, Carnegie Institute of Technology; h, 4212 Saline St, Pittsburgh, Pa.. **Mayflower 2600**

Nace, Robert R. (April 1924) Chief Engineer, Maintenance of Way, Pennsylvania R. R, 324 Pennsylvania Station, New York, N. Y; h, 539 Riverside Drive, Elizabeth, N. J.

Nagin, H. (**Associate Member**) (Dec. 1928) Secy. and Genl. Mgr, The Tri-Lock Co, 5555 Butler St, Pittsburgh, Pa............... **Fisk 2750**

Nation, Robert B. (**Associate Member**) (Oct. 1926) Sales Mgr, Monel Metal Dept, Williams & Co, Inc, 901 Pennsylvania Ave, N. S; h, 5599 Baum Blvd, Pittsburgh, Pa......................... **Cedar 2980**

Neale, Arthur (Nov. 1928) Mining Engineer, 198 West Prospect Ave, Pittsburgh, Pa.................................. **Walnut 1085**

★**Neave, Andrew A.** (Sept. 1911) V. P, Treadwell Engineering Co; h, 326 Porter St, Easton, Pa.

Neeld, A. D. Jr. (March 1919) Pres, Infusolite Company, Plum Point, Calvert Co, Md; h, Plum Point, Maryland.

Neely, Forest Hunter (March 1929) Sales Engineer, Pennsylvania Crusher Company, 1445 Oliver Bldg, Pittsburgh, Pa; h, Beaver Falls, Pa. .... **Atlantic 0839**

Neill, Benjamin Elmer (June 1928) Chief Surveyor, Real Estate Dept, Philadelphia Co, 435 Sixth Ave, Pittsburgh, Pa; h, 350 North Jefferson Ave, Canonsburg, Pa...................... **Grant 4300**

★**NEILSON, GEORGE HARRISON** (**Past President 1919**) (Feb. 1903) V. P, Water Treatment Co. of America, Grant Bldg; h, 646 Maple Lane, Sewickley, Pa.................................. **Atlantic 5490**

Nelms, George C. (**Associate Member**) (April 1927) Pres, Portable Lamp & Equipment Co, 405 Penn Ave; h, 6349 Douglas St, Squirrel Hill Sta, Pittsburgh, Pa.................................**Atlantic 0515**

Nelson, Harry Lloyd (**Associate Member**) (Oct. 1929) Acting Pittsburgh Sales Agent and Western Research Engineer, United States Pipe and Foundry Company, 412 Oliver Bldg, Pittsburgh, Pa; h, 304 Shiloh Avenue, Bellevue, Pittsburgh, Pa............**Atlantic 0767**

Nelson, James Augustus (Dec. 1928) Contracting Engineer, Steel Pipe Dept, Riter-Conley Works of the McClintic-Marshall Co, 1213 Oliver Bldg; h, Arapahoe Road, Brookside Farms, South Hills, Pittsburgh, Pa.................................**Atlantic 2562**

Nelson, Ray F. (**Associate Member**) (Dec. 1927) Draftsman, Monongahela Rwy. Co, 1200 Century Bldg; h, 1328 Pocono Street, Swissvale P. O, Pittsburgh, Pa.............................**Atlantic 5244**

Newbaker, E. J. (April 1929) General Manager, The Berwind-White Coal Mining Company, Windber, Pa; h, Windber, Pa.

Newcomer, D. A. (July 1922) Lieutenant, U. S. Engineer Office, Keenan Bldg, Pittsburgh, Pa..............................**Atlantic 5958**

Newdick, Norton A. (June 1929) Vice-President and Genl. Mgr, The Coloder Company, Inc, 568 North Fourth St, Columbus, Ohio; h, 1114 Wyandotte Road, Columbus, Ohio.

Nicholls, John A. (Feb. 1926) Asst. Engr, Bureau of City Transit, City of Pittsburgh, City-County Bldg; h, 67 Euclid Ave, Sharon, Pa.... ....**Atlantic 3900**

★**Nichols, George William** (Oct. 1909) Engr, Webb Engineering Co, Designing & Construction Engineers, 801 Oliver Bldg; h, 136 Jefferson Drive, Mt. Lebanon, Pittsburgh, Pa................**Atlantic 0265**

Nicholson, John Hancock (Feb. 1901) V. P. in charge of Sales, National Tube Co, 1827 Frick Bldg; h, 1515 Shady Ave, Pittsburgh, Pa.... ....**Atlantic 2500**

Niemann, Charles Franklin (**Associate**) (Oct. 1925) Pres, The Parkersburg Iron & Steel Co, 2003 Union Bank Bldg; h, 200 S. Linden Ave, Pittsburgh, Pa...................................**Court 1311**

Nimick, Alexander (March 1926) Chief Engr, Colonial Steel Co, 324-4th Ave, Pittsburgh, or Monaca, Pa; h, 301 Chestnut Road, Edgeworth, Sewickley, Pa....................................**Court 0582**

Noble, Howard Agnew (Nov. 1915) Pres, Pittsburgh Spring & Steel Co, 1417 Farmers Bank Bldg; h, 1245 Shady Ave, Pittsburgh, Pa. ....**Atlantic 1422**

Noble, Robert Elliott (Sept. 1912) Engr, Rolling Mill Dept, Mesta Machine Co, West Homestead, Pa; h, 45 Home Ave, Crafton, Pittsburgh, Pa................................**Homestead 1080**

Norman, Fred (May 1923) Chief Engr, Allegheny River Mining Co; h, 363 N. Jefferson St, Kittanning, Pa.................**Kittanning 1026**

★**Norris, Edward Wentworth** (Nov. 1914) Engineer, Mechanical Division Stone & Webster, Inc, 49 Federal St, Boston, Mass; h, 10 Acacia St, Cambridge, Mass.

Norris, George L. (Jan. 1911) Chief Metallurgical Engr, Vanadium Corp. of America, 120 Broadway, New York, N. Y.

Norris, William H. (Feb. 1918) Ludlum Steel Co, Watervliet, N. Y; h, 630 Western Ave, Albany, N. Y.

Norton, Paul Thornley, Jr. (Jan. 1918) Professor of Industrial Engineering, Virginia Polytechnic Institute, Blacksburg, Va; h, Blacksburg, Va.

Nourie, Leonard R. (May 1923) Sales Engineer, Sheet Metal Working, Machinery and Material Handling Equipment, 722 Park Building; h, 741 Shady Drive East, Mt. Lebanon, Pittsburgh, Pa **Atlantic 3058**

Nuernberg, Arthur (June 1918) Genl. Supt, H. Miller & Sons Co, 2565 Fifth Avenue, Pittsburgh, Pa; h, 822 Grant Street, Turtle Creek, Pa. .... **Mayflower 5240**

O'Connor, Harry D. (Jan. 1916) Engr. Pittsburgh Group, Columbia Gas and Electric Co, 824 Union Trust Bldg; h. 1835 Chellis St, N. S, Pittsburgh, Pa.................................. **Atlantic 9320**

Odell, John Dwight (Junior) (May 1926) Draftsman, The Koppers Construction Co, Koppers Bldg; h, 6304 Marchand St, Pittsburgh, Pa. .... **Atlantic 6240**

O'Donovan, James S. (May 1917) Chief Electrician, Spang-Chalfant & Co. Inc, Bridge St, Etna, Sharpsburg Sta; h, 410 Western Ave, Aspinwall, Pittsburgh, Pa......................... **Sterling 0740**

Offutt, John W. (Feb. 1919) Asst. Genl. Supt, Ellwood Wks, National Tube Co; h, 301 Glen Ave, Ellwood City, Pa.

Olin, Otto (June 1924) Mech. Engr, Standard Seamless Tube Co; h, 1212 Ohioview Ave, Ambridge, Pa.................... **Ambridge 380**

Olson, Harold M. (Feb. 1927) Dist. Mgr, The Permutit Co, 921 Union Trust Bldg; h, 171 Longue Vue Drive, Mt. Lebanon, Pittsburgh, Pa.. **Atlantic 4807**

Orr, David Kirk (Feb. 1903) Supt, The Monongahela Railway Co, Brownsville, Fayette Co, Pa; h, 462 High St, S. Brownsville, Pa...... .... **Brownsville 840-1**

★**Orr, Newell Hamilton (Associate Member)** (June 1921) Contracting Engr, Jones & Laughlin Steel Corp, Junior Beam Div; h, 1408 Termon Ave, N. S, Pittsburgh, Pa......................... **Court 3240**

Orr, Ralph Vincent (Associate) (May 1926) Sales Engr, E. W. Bliss Co, 1925 Guarantee Title Bldg, Cleveland, O; h, 238 Cochran Road, Mt. Lebanon, Pittsburgh, Pa.

Orr, Thomas E. (Feb. 1924) Dist. Sales Mgr, American Gas Accumulator Co, 2882 W. Liberty Ave; h, 316 Parkway Drive, Mt. Lebanon, Pittsburgh, Pa................................ **Lehigh 0600**

Orssten, Theodore (June 1928) Designing Eng, Aluminum Co. of America; h. 209 Meyran Ave, Pittsburgh, Pa............. **Atlantic 4545**

Osbourne, Richard Barrows (Oct. 1929) Chief Engineer, Phillips Mine and Mill Supply Company, 2227 Jane Street, Pittsburgh, Pa; h, 248 Lebanon Avenue, South Hills Branch, Pittsburgh, Pa. **Hemlock 0130**

OSLER, GEORGE F. (**Chairman Mineral Industries Section**) (Sept. 1925) President Chartiers Creek Coal Co, 218 E. Pike St, Canonsburg, Pa; h. 916 Mellon St, Pittsburgh, Pa............ **Canonsburg 956**

Osler, Jay T. (May 1911) V. P. & Gen. Mgr, Hubbard Steel Fdry. Co, East Chicago, Ind; h, 20 Highland St, Hammond, Ind.

Ottinger, Harry (Feb. 1918) Designer, National Tube Co; h, 1308 Wilson St, McKeesport, Pa.......................... **McKeesport 21174**

Oursler, John S. (Sept. 1913) Vice-President, Carnegie Steel Co, 1122 Carnegie Bldg, Pittsburgh, Pa; h, 610-10th Ave, Munhall, Pa .... **Atlantic 5100**

Ousler, George Walter (**Associate**) (Dec. 1926) Manager, Rates and Retail Service, Philadelphia Co, 435 Sixth Avenue; h, 2832 Shady Ave, Pittsburgh, Pa.............................. **Grant 4300**

Over, Raymond W. (**Associate Member**) (Dec. 1927) District Representative, Philadelphia Gear Works, 2201 Farmers Bank Bldg; Pittsburgh, Pa; h, Haysville, Pa.............................. **Atlantic 4188**

Overton, Ralph M. (**Associate Member**) (Oct. 1926) Asst. Power Engineer National Tube Co, 1606 Frick Bldg; h, 112 Atlanta Place, Mt. Lebanon, Pittsburgh, Pa.......................... **Atlantic 2500**

Owen, John E. (Feb. 1924) Steam Engr, Pittsburgh Steel Products Co, Monessen, Pa; h, 721 Broad Ave, Belle Vernon, Pa. **Monessen 360**

Packard, G. Frederick (July 1911) Equitable Life Assurance Society, 203 Frick Bldg, Pittsburgh, Pa; h, 182 Woodside Road, Wilkinsburg, Pittsburgh, Pa.................................. **Atlantic 2800**

Pacy, Ernest H. (**Associate Member**) (April 1927) Pres. & Genl. Mgr, Pittsburgh Welding Corp, 33 Water St, Pittsburgh, Pa; h, Allison Park, Pa....................................... **Court 2068**

Paddock, L. A. (May 1928) Vice Pres, American Bridge Co, Frick Bldg; h, 1504 Denniston Ave, Pittsburgh, Pa............. **Atlantic 4300**

Paff, George A. (Sept. 1912; April 1918) Supt. Rod & Wire Dept, Wheeling Steel Corp; h, 1804 Franklin Blvd, Portsmouth, Ohio.

Palmer, Charles Douglas (June 1929) Engineer of Research, Pittsburgh Railways Company, 435 Sixth Avenue; h, 220 Castle Shannon Road, Mt. Lebanon, Pittsburgh, Pa............... **Grant 7450-Line 155**

Palmer, Charles Skeele, Ph. D. (Oct. 1918) Consulting Chemical Engr: h, 4333 Dakota St, Schenley Heights, Pittsburgh, Pa **Mayflower 9170**

Paret, Henry Wilbur, Jr. (April 1928) Manager, The Gas Combustion Company, Vice-President, Duquesne Burner Service Company, P. O. Box 1753; h, The Ambassador, 4733 Centre Avenue, Pittsburgh, Pa..**Sterling 1400**

Pargny, Eugene W. (June 1902) Pres, American Sheet & Tin Plate Co, 1322 Frick Bldg; h, 1054 Beechwood Blvd, Pittsburgh, Pa...**Atlantic 1300**

Parker, Herbert E. (**Associate Member**) (June 1929) Draftsman, The Koppers Construction Co, Koppers Bldg; h, 55 N. Balph Avenue, Bellevue, Pittsburgh, Pa..........................**Atlantic 6240**

Parkin, William Metcalf (Dec. 1903; March 1913) Pres, Wm. M. Parkin & Co, 1005 Highland Bldg; h, 5577 Hampton St, Pittsburgh, Pa. ....**Montrose 0176**

Parmelee, Earle Linsley (**Associate**) (Dec. 1922) Patent Attorney, Byrnes, Stebbins & Parmelee, 1717 Farmers Bank Bldg; h, 309 LeRoi Road, Pittsburgh, Pa..................................**Atlantic 1609**

Parry, William I. (June 1910) Engr. Salesman, Carnegie Steel Co, 227 Carnegie Bldg, Pittsburgh, Pa; h, 851 Thorn St, Sewickley, Pa.. ....**Atlantic 5100-Ext. 313**

Parsons, Stanley J. (March 1917) Draftsman, H. C. Frick Coke Co. Scottdale, Pa; h, Dawson, Pa........................**Scottdale 620**

Paschedag, Charles C. (May 1906) Dist. Supt, Service & Erection, Allis-Chalmers Mfg. Co, 1209 Park Bldg; h, 2956 Voelkel Avenue, Dormont, Pittsburgh, Pa.............................**Atlantic 1729**

Passmore, Henry E. (April 1927) 5668 Darlington Road, Pittsburgh, Pa. ....**Hazel 1115**

Patterson, Peter Charles (March 1892) V. P, National Tube Co, 1714 Frick Bldg, Pittsburgh, Pa; h, 1901 Jenny Lind St, McKeesport, Pa. ....**Atlantic 2500**

Patterson, Robert F. (Oct. 1906) Plant Engr, Keystone Driller Co; h, 1226 6th Ave, Beaver Falls, Pa........................**Beaver Falls 69**

Patterson, William Joshua (Jan. 1921) Pres. & Gen. Mgr, Heyl & Patterson, Inc, 50 Water St; h, Schenley Apts, Pittsburgh, Pa......**Court 0753**

★**Paul, James W.** (Oct. 1913) Senior Mining Engr, U. S. Bureau of Mines, 4800 Forbes St; h, 619 S. Linden Ave, Pittsburgh, Pa **Mayflower 4500**

Paulsen, William R. (Oct. 1926) General Manager, American Heat Economy Bureau, Inc, 928 Wabash Bldg; h, 2035 Wendover St, Pittsburgh, Pa..................................**Court 1744**

Peale, Rembrandt (March 1922) Engineer, c/o Peale-Peacock-Kerr, Inc, St. Benedict, Pa.

Pearce, Leonard G. (Nov. 1924) Plant Engr, Pittsburgh Crucible Steel Co, Midland, Pa; h, 176 Taylor Ave, Beaver, Pa..........**Midland 51**

Pearsall, Luther Thustin (Dec. 1919) Special Engr, Jones & Laughlin Steel Corp, 3450 Second Ave; h, 14 Oakwood Road, Crafton, Pittsburgh, Pa.......... **Atlantic 9670**

Peat, D. Barr (**Associate Member**) (Dec. 1929) Vice-President and Asst. Treasurer, Issoudun Aviation Corporation, Mid City Airport, Hudson, Ohio; h, Lock Box No. 12, Dravosburg, Pa.

★**Peebles, Thomas A.** (May 1921) Vice President, Hagan Corporation, 502 Bowman Bldg; h, 31 Mt. Lebanon Blvd, Mt. Lebanon, Pittsburgh, Pa.......... **Court 4724**

Peirce, Charles L., Jr. (April 1923) Pres, Hubbard & Co, 6301 Butler St; h, 1424 Beechwood Blvd, Pittsburgh, Pa.......... **Fisk 1333**

Peirce, W. Bradford (March 1923) Works Manager, Pittsburgh Screw & Bolt Co, Graham Works, Neville Island Branch, Pittsburgh, Pa; h, 219 Meadow Lane, Edgeworth, Sewickley, Pa...... **Federal 1240**

★**Pendleton, Dudley D.** (Dec. 1911) Dist. Mgr, Foster Wheeler Corp, 1439 Oliver Bldg; h, 1209 Wightman St, Pittsburgh, Pa... **Atlantic 2844**

Perkins, Thomas S. (Jan. 1901) Mgr, Supply Engrg. Dept, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, Grey Hall, Irwin, Pa.......... **Brandywine 1500**

Perrott, G. St. J. (Dec. 1927) Superintendent, U. S. Bureau of Mines, 4800 Forbes St; h, 5316 Liberty Avenue, Pittsburgh, Pa.. **Mayflower 4500**

Peters, F. G. (**Associate Member**) (May 1927) Sales Engr, H. H. Robertson Co, Grant Bldg, Pittsburgh; h, 927 Main St, Coraopolis, Pa.......... **Atlantic 3200**

Peterson, Harry Oscar (**Student Junior**) (June 1928) Surveying Crew, U. S. Engineering Company, 5035 Forbes St, Pittsburgh, Pa; h, 248 South 15th Street, Sebring, Ohio.......... **Schenley 9265**

Peterson, Victor Henry (Dec. 1926) Sales Engr, Elliott Co, 718 Frick Bldg; h, 5660 Munhall Road, Pittsburgh, Pa........ **Atlantic 5000**

Peth, Herbert William (Oct. 1927) Engr, John F. Casey Co, Box 1753; h, 208 Eastern Avenue, Aspinwall, Pittsburgh, Pa....... **Sterling 1400**

Pettay, George Theodore (**Associate Member**) (March 1921) Member of Firm, Aires, Stone & Pettay, 6th Floor, 335 Blvd. of Allies; h, 3411 Terrace St, Pittsburgh, Pa.......... **Court 0128**

Pharo, Harry A. (Dec. 1924) Pres, Pharo Engineering Co, 517 Park Bldg, Pittsburgh, Pa; h, 600 North Ave, Wilkinsburg, Pittsburgh, Pa.......... **Atlantic 0888**

Phillips, Fernley Berrington (**Student Junior**) (Sept. 1927) Student, Electrical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa; h, 827 Kirkpatrick Ave, N. Braddock, Pa...... **Brandywine 1931-J**

PHILLIPS, FRANK REITH (**Vice President**) (Sept. 1913) Senior Vice President, Philadelphia Company, 435-6th Ave; h, 190 Orchard Drive, Mt. Lebanon, Pittsburgh, Pa.......... **Grant 7450**

Phillips, John M. (March 1898) Pres, Phillips Mine & Mill Supply Co; h, 2227 Jane St, Pittsburgh, Pa........................ **Hemlock 0130**

Phillips, Leslie (Dec. 1926) Design Engineer, Pittsburgh Branch, Byllesby Engrg. & Management Corp, 435 Sixth Ave, Pittsburgh, Pa; h, 964 Jackman Ave, Avalon, Pittsburgh, Pa.... **Grant 5750-Line 577**

Pierce, Lonnie J. (May 1917) Chf. Engr, American Window Glass Co, 1622 Farmers Bank Bldg; h, 6649 Woodwell St, Squirrel Hill Sta, Pittsburgh, Pa................................ **Atlantic 0450**

Pinkerton Andrew (Nov. 1907) Electrical Engr, American Sheet & Tin Plate Co, Box 427, 1115 Frick Bldg, Pittsburgh, Pa; h, 6605 Virginia Ave, Ben Avon, Pittsburgh, Pa.................. **Atlantic 1300**

★**Pittman, Ernest Walter** (Feb. 1903) Chief Engineer, The Petroleum Iron Works, Beaumont, Texas.

Polhemus, Dudley Abram (April 1912) District Manager, American Engineering Co, 2147 Oliver Bldg; h, 2703 Norwood St, Pittsburgh, Pa. .... **Atlantic 2342**

Poling, Murray Yost (June 1929) Geodetic Engineer, R. H. Randall & Company, 914 City-County Building; h, Ruskin Apartments, Pittsburgh, Pa................................ **Atlantic 3900-Line 277**

Polk, Robert Edmund (June 1919) Genl. Mgr, Equitable Sales Co, 427 Liberty Ave; h, 853 Taylor Avenue, Avalon, Pittsburgh, Pa..... .... **Grant 3200-279**

Porter, George Jr. (Oct. 1923) Bureau of Water, City of Pittsburgh, 310 City-County Bldg; h, 420 Neville St, Pittsburgh, Pa.......... .... **Atlantic 3900-Ext. 66**

Porter, Henry Tegmeyer (Oct. 1906) Chief Engr, Bessemer & Lake Erie R. R. Co, 160 Main St; h, 334 Main St, Greenville, Pa.

Porter, Rudyard (Feb. 1924) Representative, Operating Dept, American Sheet & Tin Plate Company, 902 Frick Bldg; h, 1519 Bailey Avenue, McKeesport, Pa................................ **Atlantic 1300**

Postlethwaite, Clarence E. (Feb. 1903) Assistant Vice-President, Pressed Steel Car Co, 55 Broad St, New York, N. Y; h, 142 Hamilton Ave, New Rochelle, N. Y.

Pote, Kenneth E. (**Associate Member**) (June 1929) District Manager, Riley Stoker Corp, 1419 Farmers Bank Bldg; h, 259 Melwood Street, Pittsburgh, Pa................................ **Atlantic 0875**

Powel, Charles A. (Dec. 1926) Gen. Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 634 S. Linden Ave, Pittsburgh, Pa...... .... **Brandywine 1500**

Powelson, Frank W. (June 1924) Civil Engr, Pressed Steel Car Co, 19th Floor, Farmers Bank Bldg; h, 3065 Zephyr Ave, Pittsburgh, Pa. .... **Federal 0740**

Prentice, Hugh (Jan. 1913) Engr. & Salesman, Impervious Varnish Co; 421 Wood St; h, 3918 Brandon Road, N. S, Pittsburgh, Pa. . **Atlantic 0215**

Price, Philip Wallis (March 1915) Assistant Construction Engr, Bureau of Bridges, Dept. of Public Works, Allegheny County, 519 Smithfield St; h, 6950 Rosewood St, Homewood Sta, Pittsburgh, Pa. .... **Atlantic 4900-Line 45**

Pringle, W. Dick (Associate Member) (Feb. 1925) Sales Engr, The W. S. Tyler Co. of Cleveland; h, 6648 Wilkins Ave, Pittsburgh, Pa.... .... **Hazel 0219**

Provan, John Stevenson (Associate Member) (Feb. 1927) Junior Engr, Morris Knowles, Inc, 507 Westinghouse Bldg; h, 540 Seagirt St, Pittsburgh, Pa.................................... **Atlantic 3882**

Provost, George W. (Associate) (May 1912) President, Doubleday-Hill Electric Co, 110-12 Seventh St; h, 5808 Beacon St, Pittsburgh, Pa... **Atlantic 3000**

Pryde, David (April 1911) Manager of Works, Superior Steel Corp, Carnegie, Pa; h, 19 3rd St, Aspinwall, Pittsburgh, Pa... **Carnegie 23**

Pugh, George A. (Junior) (Feb. 1918) Vice-President, The Aetna Standard Engineering Co, Home Savings & Loan Bldg, Youngstown, Ohio; h, 21 Second St, Ellwood City, Pa.

Purcell, Thomas Edward (Jan. 1928) Gen. Supt. of Power Stations, Duquesne Light Co, 435 Sixth Ave; h, 5526 Wilkins Ave, Pittsburgh, Pa. .... **Grant 4300-Ext. 218**

Querbach, Earl (April 1912) Structural Engr, American Bridge Co, Ambridge, Pa; h, 857 Jackman Ave, Avalon, Pittsburgh, Pa. **Ambridge 398**

Quinn, Robert S. (Feb. 1928) Asst. Genl. Supt, Carnegie Steel Co, Mingo Junction, O; h, 633 Lawson Ave, Steubenville, O.

Rabberman, A. Leslie (Associate) (May 1924) V. P. and Treas, Pennsylvania Drilling Co, 1812 W. Carson St; h, 3444 Universal St, Corliss Sta, Pittsburgh, Pa................................ **Walnut 1783**

Ralston, William S. (Oct. 1904) V. P, Chaplin-Fulton Mfg. Co, 36 Penn Ave; h, 6620 Kinsman Road, Pittsburgh, Pa............ **Court 1201**

Ramsburg, Charles J. (June 1916) V. P, The Koppers Co, 1650 Koppers Bldg, Pittsburgh; h, 5 East Drive, Edgeworth, Sewickley, Pa...... .... **Atlantic 6240**

Ramsey, John Negley (May 1923) Partner, Vegeler Ramsey & Co, 208 Bowman Bldg; h, 6 Promenade St, Crafton, Pittsburgh, Pa. **Court 4078**

Rankin, Harry Howard (April 1901; Sept. 1908) Civil Engineer, Private Practice, 309 Fourth Ave; h, 7012 Reynolds St, Pittsburgh, Pa... .... **Court 3628**

Rapp, Ralph Lehmer (Oct. 1925) Sales Engr, General Electric Co, 1314 Oliver Bldg; h, 203 Maybrick Ave, Mt. Lebanon, Pittsburgh, Pa. .... **Atlantic 6400**

Rassbach, Richard William (Dec. 1928) Mechanical Engineer, The Rust Engineering Co, Koppers Bldg; h, 5123 Center Ave, Pittsburgh, Pa..**Atlantic 8870**

★**Rayburn, John M.** (March 1903; Sept. 1912) Civil & Mining Engr, 1115 House Bldg; h, 126 Prospect Ave, Ingram, Pittsburgh, Pa..**Court 3579**

★**RAYMER, ALBERT R.** (**Past President 1914**) (June 1902) Asst. Vice Pres. & Chief Engr, P&LE R. R.Co, P&LE Terminal Bldg, Pittsburgh, Pa; h, 258 Taylor Ave, Beaver, Pa.............**Court 3201**

Rederer, Benedict S. (Nov. 1912) Mgr, B. S. Rederer & Co, 513 Arrott Bldg; h, 384 Avon Drive, Mt. Lebanon, Pittsburgh, Pa..**Court 0485**

Reed, Chester A. (March 1928) Chief Combustion Engineer, Pittsburgh Coal Company, 1027 Oliver Bldg; h, 28 Hazel Drive, Mt. Lebanon, Pittsburgh, Pa.................................**Atlantic 2181**

Reed, Louis J. (Feb. 1924) Asst. Chief Engineer, Aliquippa Works, Jones & Laughlin Steel Corp, Aliquippa, Pa; h, 123 Orchard Street, Aliquippa, Pa.................................**Aliquippa 101**

Reed, Norman J. (**Associate Member**) (May 1926) Sales Repr, Allis Chalmer Mfg. Co, 1209 Park Bldg; h, 2718 Espy Ave, Dormont, Pittsburgh, Pa..**Atlantic 1729**

Reed, Van A. Jr. (Sept. 1924) Secy, Federal Engineering Co, 1420 Investment Bldg, 239 Fourth Avenue, Pittsburgh, Pa; h, Elizabeth, Pa...**Court 2672**

★**Reed, William Edgar** (Jan. 1907) Consulting Engr, 577 Union Trust Bldg; h, 5101 Fifth Ave, Pittsburgh, Pa..................**Atlantic 0478**

Rees, Thomas M. (Jan. 1880) Pres, James Rees & Sons Co, Box 709; h, 400 Morewood Ave, Pittsburgh, Pa....................**Grant 0389**

Reese, David M. (March 1923) Designer, Carnegie Steel Co, Clairton, Pa; h, Mingo Road, R. D. No. 2, Finleyville, Pa..........**Clairton 5 R-8**

Reese, Oliver P. (Dec. 1927) Genl. Supt, Pennsylvania R. R. System, 310 Union Station, Indianapolis, Ind.

Reich, Philip J. (May 1922) Div. Engr, American Bridge Co, 1424 Frick Bldg; h, 7006 Flaccus Road, Ben Avon, Pittsburgh, Pa..**Atlantic 4300**

Reilley, Louis D. (March 1928) Manager, Ambridge Plant, American Bridge Co, Ambridge, Pa; h, 526 Park Road, Ambridge, Pa...**Sewickley 1003**

Reisinger, Horace W. (June 1918) Manufacturers' Agent, 710 Park Bldg; h, C-3 Alder Court, Alder & Emerson Sts, E. E. Pittsburgh, Pa...**Atlantic 1208**

★**Renkin, William O.** (Feb. 1916) Chief Engineer, Dry Quenching Equipment Corp, 200 Madison Ave, New York, N. Y; h, P. O. Box 423, Oradell, N. J.

Reno, Edwin S. (July 1917; Oct. 1926) Certified Public Accountant, Price, Waterhouse & Co, 1518 Grant Bldg, Pittsburgh, Pa; h, 401 Highland Ave, West View, Pa........................**Grant 3457**

Renshaw, David E. (Oct. 1928) Genl. Engr, Westinghouse Elec. and Mfg. Co. East Pittsburgh, Pa; h. 466 Cascade Road, Edgewood Acres, Wilkinsburg, Pittsburgh, Pa..................**Brandywine 1500**

Renton, Walter C. (**Associate Member**) (Dec. 1924) Asst. Chief Draftsman, Union Switch & Signal Co, Swissvale, Pa; h, 110 Oakview Ave, Edgewood, Pittsburgh, Pa......................**Penhurst 0880-280**

★**Reppert, Charles M.** (June 1910) Chief Engr, Dept. Public Works, City of Pittsburgh, 418 City-County Bldg; h, 325 S. Dallas Ave, E. E, Pittsburgh, Pa..............................**Atlantic 3900**

Rice, Cyrus William (June 1922) Cyrus William Rice & Co, Water Purification Engineers and Chemists, Highland Bldg; h, 938 Farragut St, Pittsburgh, Pa..............................**Montrose 4239**

Rice, John M. (Feb. 1903; Dec. 1915) Consulting Engineer, Private Practice, 245 Oliver Bldg; h, 5435 Black St, Pittsburgh, Pa.....**Atlantic 4738**

Rice, W. E. (**Associate Member**) (Feb. 1928) Asst. Fuel Engr, U. S. Bureau of Mines, 4800 Forbes St; h, 1830 Beechwood Blvd, Pittsburgh, Pa. ....**Mayflower 4500**

Richards, Earl Morgan (Nov. 1925) Chief Industrial Engineer, Aliquippa Works, Jones & Laughlin Steel Corp, Aliquippa, Pa; h, 307 Third St, Beaver, Pa..............................**Aliquippa 101**

Richardson, Charles Parker (**Associate Member**) (Oct. 1927) Dravo-Doyle Company, 1256 Builders' Bldg, Chicago, Ill.

Richardson, Joseph George (Sept. 1912) Civil Engr; h, 2622 Norwood Ave, N. S. Pittsburgh, Pa............................**Fairfax 6596**

Riddle, Lawrence Edward (March 1914) Gen. Supt, City Blast Furnace, Carnegie Steel Company, c/o Isabella Furnaces, Sharpsburg, Pa; h, 717 Duquesne Blvd, Duquesne, Pa..............**Sterling 1500**

Riddle, Louis M. (**Associate**) (April 1928) Sales Engineer, Ochiltree Electric Co, 505 Liberty Ave; h, 1459 Kelton Ave, Dormont, Pittsburgh, Pa..................................**Atlantic 1900**

Ridinger, Charles Wesley (Oct. 1896) Pres, Iron City Engineering Co, 3rd Ave. and Grant Street, and Iron City Electric Co, 575 Sixth Ave; h, 5830 Marlborough St, Squirrel Hill, Pittsburgh, Pa...... ....**Atlantic 9100**

Riegel, Clarence L. (**Associate**) (Oct. 1924) Asst. to Mgr, General Electric Co, 1309 Oliver Bldg; h, 3432 Clearfield St, Corliss Sta, Pittsburgh, Pa.......................................**Atlantic 6400**

★**Riegel, Ross Milton** (Oct. 1925) Departmental Designing Engr, Dept. Public Works, City of Pittsburgh, 420 City-County Bldg; h, 1132 Murrayhill Avenue, Pittsburgh, Pa................**Atlantic 3900**

Rieger, William H. (Oct. 1924) Pittsburgh Sales Mgr, A. Finkl Sons Co h, 212 Virginia Avenue, Aspinwall, Pittsburgh, Pa . . **Sterling 2435**

Riegler, L. J. (Nov. 1924) Asst. Engr, Pennsylvania R. R. Co, 1126 Pennsylvania Station, Pittsburgh, Pa; h, 7028 Church Ave, Ben Avon, Pittsburgh, Pa. . . . . **Grant 6000-Ext. 94**

Riley, Albert Dowler (May 1918) Mech. Engr, Standard Chemical Co, Canonsburg, Pa; h, 42 Creighton Ave, Crafton, Pittsburgh, Pa. . . . . **Canonsburg 84**

Rinehart, Edward Everett (March 1921) Construction Engr, W. T. Grange Construction Co, 803 Keenan Bldg; h, 3401 Massachusetts Ave, N. S. Pittsburgh, Pa . . . . **Atlantic 5754**

Rittman, Walter F. (Dec. 1926) Professor, Commercial Engineering, Carnegie Institute of Technology, Pittsburgh, Pa . . . **Mayflower 2600**

Ritts, Arch V. (June 1919) Chief Engr, Costello Engineering Co, 519 Oliver Bldg, Pittsburgh; h, Wyland Ave, Allison Park, Pa . . **Atlantic 1493**

Ritts, William Henry (Associate) (April 1913) Steam Engr, Spang Chalfant & Co, Inc, Bridge St; h, 7 Pine St, Etna, Pa. . . . . **Sterling 0740**

Robbins, Charles (May 1921) Pres. and Treas, Robbins Electric Co, 830 Liberty Ave, Pittsburgh, Pa. . . . . **Atlantic 5900**

Roberts, G. Braden (Associate Member) (Oct. 1929) Sr. Eng. of Design, Allegheny County, 519 Smithfield Street, Pittsburgh, Pa; h, 2815 Voelkel Avenue, Dormont, Pittsburgh, Pa . . . . **Atlantic 4900**

Roberts, Grant W. (Feb. 1929; Nov. 1929) 533 Brookline Blvd, S. H. Branch, Pittsburgh, Pa.

Roberts, James Milnor (Nov. 1914) Contracting Civil Engr, Riter-Conley Works of the McClintic-Marshall Company, Oliver Bldg; h, 1206 N. Negley Avenue, Pittsburgh, Pa. **Atlantic 2562**

Robertson, A. W. (Feb. 1929) Chairman of Board, Westinghouse Electric & Mfg. Co, 1923 Grant Bldg; h, R. F. D. No. 6, Brownsville and Fairhaven Roads, Mt. Oliver Station, Pittsburgh, Pa . . **Atlantic 8400**

Robertson, David (Feb. 1927) Gen. Supt, Keystone Mining Co; h, East Brady, Pa. . . . . **East Brady 39**

Robertson, Harold Hansard (Associate) (June 1918) Pres. H. H. Robertson Company, Grant Bldg; h, Park Mansions, Schenley Park, Pittsburgh, Pa. . . . . **Atlantic 3200**

Robertson, Ralph N. (Jan. 1927) Mechanical Engineer, Blaw-Knox Company, P. O. Box 915, Pittsburgh Pa; h, 1100 Lancaster Avenue, Pittsburgh, Pa. . . . . **Sterling 2700**

Robey, Harry F. (Associate) (Oct. 1928) Industrial Engineer, Aluminum Company of America, 2400 Oliver Building; h, 416 Greendale Avenue, Edgewood, Pittsburgh, Pa. . . . . **Atlantic 4545**

Robinson, John C., Jr. (Sept. 1928) Draftsman, The Koppers Company, Koppers Bldg; h, 1250 S. Negley Avenue, Pittsburgh, Pa.. **Atlantic 6240**

Robinson, J. French (Jan. 1925) Engr. & Geologist, Peoples Natural Gas Co. 545 William Penn Way; h, 1849 Shaw Ave, Squirrel Hill Sta, Pittsburgh, Pa.................................... **Grant 5100**

Robinson, Mayes Randolph (Associate Member) (Dec. 1925) Sales Engr, Bushnell Machinery Co, 1501 Grant Bldg; h, 424 McCully St, Mt. Lebanon, Pittsburgh, Pa.............................. **Atlantic 0417**

Rockwell, Willard F. (Dec. 1928) President, Pittsburgh Equitable Meter Company, Director, Aero Corp. of America, 400 North Lexington Avenue, Pittsburgh, Pa; h, 140 Hutchinson Ave, Edgewood, Pittsburgh, Pa.................................... **Churchill 8400**

Rodd, Thomas(Jan. 1880) Retired Chief Engineer, The Pennsylvania Railroad Company, 1134 Pennsylvania Station; h, 5407 Ellsworth Avenue, Pittsburgh, Pa.............................. **Grant 6000**

Rodgers, Edward H. (Oct. 1904) American Sheet & Tin Plate Co, Farrell Works, Farrell, Pa; h, 1224 Washington St, Farrell, Pa. **Farrell 1200**

Rodgers, J. Franklin (June 1920) Asst. Dist. Sales Mgr, Elliott Co, 718 Frick Bldg; h, 1144 Wightman St, Pittsburgh, Pa..... **Atlantic 5000**

Rodgers, W. P. (Dec. 1923) Civil & Mining Engr, Independent, Box 564, Monongahela, Pa........................ **Monongahela City 830**

Rodman, Clarence James (April 1929) President and Treasurer, Steel Sanitary Company, Buckeye Jack Mfg. Company, Hill Top Oil Company, Box 869; h, 541 Overlook Drive, Alliance, Ohio.

Ross, Theodore H. (Sept. 1922) Dist. Mgr, Skinner Engine Co, 1409 Oliver Bldg, Pittsburgh; h, 315 Morrison Ave, Mt. Lebanon, Pittsburgh, Pa.. **Atlantic 2014**

Roth, James Dorsey (Associate) (Dec. 1926) Valuation Engineer, Philadelphia Company, 435 Sixth Avenue; h, King Edward Apts, Bayard St, Pittsburgh, Pa................. **Grant 3200-Ext. 595**

Rowland, Roger W. (Oct. 1926) President, New Castle Refractories Company, P. O. Box 193; h, 1000 Highland Avenue, New Castle, Pa.

Roy, R. J. (Associate Member) (Dec. 1928) Mgr, Fairbanks Morse & Co, 1003 Law & Finance Bldg; h, 714 Wisteria Ave Mt. Lebanon, Pittsburgh, Pa.................................. **Atlantic 6761**

Rudd, Harold H. (Dec. 1926) V. P, Railway and Industrial Engineering Co; h, N. Westmoreland Ave, Greensburg, Pa.... **Greensburg 1527**

Rugg, W. S. (Sept. 1924) Vice Pres, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, University Club, 123 University Place, Pittsburgh, Pa.. **Brandywine 1500**

Ruhe, C. H. William (Nov. 1889) Mech. Engr. & Accountant; h, 1223 La Clair Ave, Swissvale Branch, Pittsburgh, Pa......... **Penhurst 4175**

Rush, Ralph M. (Feb. 1913) Pres. Rush Machinery Co, 32 E. Carson St. h, 1341 Heberton Ave, Pittsburgh, Pa................ **Court 1520**

Rust, Harry B. (June 1910) Pres. The Koppers Co, 1500 Koppers Bldg; h, 1177 Murrayhill Ave, Pittsburgh, Pa................ **Atlantic 6240**

Rust, Stirling Murray (May 1922) Pres, The Rust Engineering Co, Koppers Bldg; h, 1156 S. Negley Ave, Pittsburgh, Pa........ **Atlantic 8870**

Rust, William F. (Jan. 1925) Vice-Pres, The Koppers Construction Co, Koppers Bldg; h, 1180 Murrayhill Ave, Pittsburgh, Pa. **Atlantic 6240**

★**Ruud, Edwin** (Jan. 1888) Pres, Ruud Mfg. Co, 29th & Smallman Sts; h, 240 S. Graham St, Pittsburgh, Pa........................ **Grant 6688**

Ryan, John T. (May 1921) V. P. & Gen. Mgr, Mine Safety Appliances Co, Cor. Braddock Ave. & Thomas Blvd; h, 120 S. Richland Lane, Pittsburgh, Pa................................ **Churchill 5900**

Ryman, Charles Franklin (Junior) (Dec. 1924) Sales Engr, Reading Chain & Block Corp, 1302 Commonwealth Bldg; h, 1653 Potomac Ave, Dormont, Pittsburgh, Pa......................... **Court 3257**

Rys, C. F. W. (April 1910) Asst. to Pres. and Metallurgical Engr, Carnegie Steel Co, 517 Carnegie Bldg; h, 5463 Aylesboro Ave, Pittsburgh, Pa.. **Atlantic 5100**

Saeger, Geoff A. (May 1927) Chemical Engineer, Missouri Portland Cement Company, Telephone Bldg, St. Louis, Mo.

Sanford, H. Starkey (Jan. 1903) Manager of Sales, Riter-Conley Co, 39 Broadway, New York City; h, Kew Gardens Inn, Kew Gardens, Long Island, N. Y.

Sangdahl, George Stanley (March 1928) Mgr, Cleveland Office, Chicago Bridge & Iron Works, 1657 Union Trust Bldg, Cleveland, O; h, 1210 West Lake Ave, Lakewood, Ohio.

Sanville, Walter F. (**Associate Member**) (May 1922) 411 Boulevard of the Allies; h, Schenley Arms, Pittsburgh, Pa.......... **Court 4262**

Saurbrey, Henry Alexis d'Origny (**Associate Member**) (May 1926) Chief Engr, Mellon-Stuart Co, 2112 Oliver Bldg, Box 1114; h, 5865 Alderson St, Pittsburgh, Pa...................... **Atlantic 0803**

Savage, Luke F. (Feb. 1924) City Engr, City of McKeesport, Peoples Bank Bldg; h, 3003 Versailles Ave, McKeesport, Pa.... **McKeesport 22303**

Sborigi, Guido V. (Dec. 1926) Pres, Taylor-Wilson Mfg. Co, McKees Rocks, Pa; h, 86 King Edward Apts, Bayard St, Pittsburgh, Pa. **Federal 0171**

Schade, Charles G. (Sept. 1892) Chief Engr. & Works Mgr, Fort Pitt Bridge Works; h, 215 Smithfield St, Canonsburg, Pa........ **Canonsburg 27**

Schaller, Robert H. (**Associate Member**) (May 1923) Supt, By-Product Coke Plant, Aliquippa Works, Jones & Laughlin Steel Corp; h, 601 Burton St, Aliquippa, Pa.................. **Aliquippa 101-Ext. 13**

★**SCHARFF, MAURICE R.** (**Silver Medal 1920**) (Jan. 1913) Consulting Engr, Associated with Main & Co, 19th Floor, First National Bank Bldg; h, 26 Gladstone Road, East End, Pittsburgh, Pa. **Atlantic 3156**

Schatz, Fred C. (May 1901) Asst. Mgr, Jos. Horne Co, 501 Penn Ave; h, 741 Broughton St, E. E. Pittsburgh, Pa............ **Court 3000**

SCHAUER, FRANK F. (**Director**) (May 1924) Vice Pres. & Genl. Mgr, Equitable Gas Co, 435 Sixth Ave; h, 1454 Shady Ave, Pittsburgh, Pa................................. **Grant 7600-Line 55**

Scheib, Walter H. (June 1922) Sales Engr, Tate Jones & Co, Inc, 519 Oliver Bldg; h, 353 Marshall Ave, N. S. Pittsburgh, Pa..... **Atlantic 1493**

Schein, Nathan (**May 1922**) Div. Engr, City of Pittsburgh, 419 City-County Bldg; h, 1341 Shady Ave, Pittsburgh, Pa............ **Atlantic 3900**

Schenck, Rand Gilmore (**Associate Member**) (Oct. 1927) Sales Engr, Fiske Bros. Refining Co, Box 73, Cheswick, Pa.

Schiller, William B. (Jan. 1921) Retired; h, 5075 Forbes St, Pittsburgh, Pa.

Schmitz, Edwin H. (March 1928) District Mgr, Riley Stoker Corp, 1419 Farmers Bank Bldg; h, 5660 Munhall Road, Pittsburgh, Pa... **Atlantic 0875**

Schneider, Reinhold (March 1917) Chief Engr, Farrell & Sharon Works, Carnegie Steel Co, Farrell, Pa; h, 334 E. State St, Sharon, Pa.

Schneider, Robert A. (April 1921) Civil Engr. and Land Surveyor, 2706 Brownsville Road, Carrick, Pittsburgh, Pa............ **Carrick 0895**

Schuchert, Joseph S. (Dec. 1926) Supervisor, Architects & Builders Service, Duquesne Light Company, 435 Sixth Avenue; h, 3000 Clermont Ave, Brentwood, Pittsburgh, Pa..................... **Grant 4300**

Schuchman, Bertram F. (June 1912) Treas. Homestead Valve Mfg. Co, Box 278; h, Homestead, Pa..................... **Homestead 1701**

Schultz, Ferdinand George (**Associate**) (September 1929) Proprietor, Ferdinand G. Schultz Co, Mill and Foundry Equipment, 1125 Park Bldg; h, 215 Questend Ave, Mt. Lebanon, Pittsburgh, Pa... **Atlantic 1607**

Schultz, Herbert A. (Oct. 1928) Manufacturers' Agent, Moore Steam Turbine, Garling Turbine Blower Corp, Andale Co, American Manganese Bronze Co, 205 Oliver Building; h, 410 Bucknell St, Pittsburgh, Pa.................................... **Atlantic 0147**

Schulze, Arthur R. (Oct. 1908) Asst. Chf. Engr, Mingo Works, Carnegie Steel Co, Mingo Junction, O; h, 300 South Bend Blvd, Steubenville, Ohio.

★**SCOTT, CHARLES FELTON** (**Past President 1902**) (April 1890) Professor of Electrical Engineering, Sheffield Scientific School of Yale University; h, 19 Trumbull St, New Haven, Conn.

Scott, J. Walter (March 1925) Senior Conduit Inspector, The Bell Telephone Co. of Penna, 416-7th Ave; h, 315 S. Fairmount Ave, Pittsburgh, Pa.. **Official 0050**

Scott, Maxwell William (Oct 1924) Mgr, Penn Machinery & Equipment Co, 2138 Oliver Bldg; h, 5928 Walnut St, Pittsburgh Pa . . . . **Atlantic 2274**

Scott, Samuel A. (Dec 1902) V. P. & Gen. Mgr, The New River Co; h, MacDonald, W. Va.

Scott, Warren Randolph (April 1924) Cons. Engr, 1302 Lynch Bldg, Jacksonville, Fla; h, 2335 Riverside Avenue, Jacksonville, Fla.

★**Seaver, Kenneth** (May 1910) Vice President, Harbison-Walker Ref. Co, Farmers Bank Bldg, Pittsburgh, Pa; h, Hulton Road, Oakmont, Pa .... **Atlantic 0942**

See, Theodore S. (July 1917) President, Pennsylvania Fabrication Co, Verona, Pa; h, 1321 Malvern Ave, Pittsburgh, Pa. . . **Oakmont 1**

Seidle, Norman R. (**Associate**) (Dec. 1924) Gen. Mgr, McAleenan Bros. Co, 25th St. & A. V. R. R, Pittsburgh, Pa; h, 209 Alden Rd, Rosslyn Farms, Carnegie, Pa .... **Atlantic 6540**

Seipp, Henry C. (March 1929) Sales Engineer, Art Metal Construction Company, 315 Oliver Bldg; h, 153 Morewood Avenue, Pittsburgh, Pa .... **Atlantic 1734**

Seldon, Henry William (April 1912) Supt, United Alloy Steel Corp; h, 1316-10th St, N. W, Canton, O.

Selkirk, William Marshall (Dec. 1920) Chief Engr, Seamless Tube Div, Pittsburgh Steel Co, Monessen, Pa; h, 725 Broad Ave, North Belle Vernon, Pa .... **Monessen 360**

Selquist, Rolf (Nov. 1929) Electrical Engineer, Copperweld Steel Company, Glassport, Pa; h, Penn McKee Hotel, McKeesport, Pa.

Senn, Charles Moyer (Oct. 1924) Draftsman, Wellman-Seaver-Morgan Co, 7100 Central Ave; h, Suite 3, 2806 Lorain Ave, Cleveland, O.

Severn, Arthur B. (March 1925) Gen. Mgr, A. Stucki Co, 419 Oliver Bldg; h, 1201 Chelton Ave, Dormont, Pittsburgh, Pa .... **Atlantic 1250**

Shafer, William B. (March 1926) V. P, Pittsburgh Asphalt Vault Co, 806 Federal Reserve Bank Bldg; h, 5455 Bartlett St, Pittsburgh, Pa . . . . **Sterling 1939**

Shaw, George M. (Jan. 1903) Sales Rep, Standard Steel Car Co, Box 248, h, 922 University Parkway, Baltimore, Md.

Shaw, Hugh Campbell (**Associate**) (June 1921) Pres. Shaw-Perkins Mfg. Co, 1643 Oliver Bldg; h, 2200 Beechwood Blvd, Pittsburgh, Pa. .... **Atlantic 2044**

Shaw, Norman L. (Nov. 1907) Draftsman, Pressed Steel Car Co, McKees Rocks, Pa; h, 568 Orchard Ave, Bellevue, Pittsburgh, Pa . **Federal 0740**

★**Shaw, William** (Nov. 1921) Power Engr, Mechanical Div. Bureau of Water, City of Pittsburgh, 309 City-County Bldg; h, 3601 Dawson St, Oakland Sta, Pittsburgh, Pa .... **Atlantic 3900-Ext. 204**

Shepherd, Alexander Boteler (Feb. 1903) Second Vice Pres, Monongahela Connecting R. R, Third & Ross St; h, 420 Emerson St, Pittsburgh, Pa..**Court 3241**

Sherratt, Gayle F. (May 1925) Dist. Mgr, Chain Belt Co. of Milwaukee, Wis, 704 Magee Bldg; h, 6537 Wilkins Ave, E. E, Pittsburgh, Pa. ....**Court 1430**

Shipley, Grant B. (Dec. 1912) President, Century Wood Preserving Co, 3010 Koppers Building; h, 5398 Hobart St, Pittsburgh, Pa........ ....**Atlantic 4955**

Shiras, MacGilvray (May 1902) Ore Agent, Carnegie Steel Company, 820 Carnegie Bldg; h, 5746 Aylesboro Avenue, Pittsburgh, Pa...... ....**Atlantic 5100**

Shirk, William Blottenberger (Nov. 1928) Steel Mill Engineer, Westinghouse Electric & Mfg. Co, East Pittsburgh, Pa; h, 504 Avenue "D", Wilkinsburg, Pittsburgh, Pa....................**Brandywine 1500**

Shoffstall, Arthur S. (Sept. 1922) Gen. Mgr, The International Nickel Co, Box 1570; h, 535-11th Ave, Huntington, W. Va.

Shook, John Edward (Oct. 1923) Sales Engineer, Foster Wheeler Corp, 1405 Oliver Building; h, 5 Main St, Overbrook Boro, Mt. Oliver Sta, Pittsburgh, Pa.............................**Atlantic 2844**

Shotton, Bruce Gillespie (Oct. 1927) Dist. Sales Mgr, Hendrick Mfg. Co. of Carbondale, Pa, 981-B Union Trust Bldg; h, 235 Academy Ave, Mt. Lebanon, Pittsburgh, Pa......................**Atlantic 1648**

★**Shover, Barton Roy** (May 1921) Consulting Engineer, 441 Oliver Bldg; h, 4733 Wallingford St, E. E, Pittsburgh, Pa...........**Atlantic 1893**

Shriner, Edward Coleman (Associate) (May 1922) Sales Engineer, Consolidated-Ashcroft-Hancock Co, Inc, 1411 Park Building; h, 1710 Potomac Avenue, Dormont, Pittsburgh, Pa.....**Atlantic 6630**

Shrom, William G. (Nov. 1911; Jan. 1923) Jones & Laughlin Steel Corp; h, 109 Shaw Street, Aliquippa, Pa..............**Aliquippa 519-W**

Shultz, Frank W. (Feb. 1918) Steam & Hydr. Engr, National Tube Co; h, 2118 East 9th Ave, McKeesport, Pa...........**McKeesport 4144**

Shuman, Jesse J. (April 1907) Inspecting Engr, Jones & Laughlin Steel Corp, Third Ave. & Ross St; h, 931 Sheridan Ave, Pittsburgh, Pa.**Court 3240**

Shupe, H. Parker (Associate) (Dec. 1924) Electrician, P. P. Robinson Co. Inc; h, 5834 Ellsworth Ave, E. E. Pittsburgh, Pa....**Montrose 7659**

Siefers, George Francis (April 1921) Civil Engr, G. F. Siefers Co, 541 Wood St; h, 210 Biddle Ave, Wilkinsburg, Pittsburgh, Pa........ ....**Atlantic 3824 & Churchill 0494**

Simons, E. S. (June 1927) Pres, Pittsburgh Reflector Co, 400 Bowman Bldg, Pittsburgh, Pa; h, 513 Hill Ave, Wilkinsburg, Pittsburgh, Pa..... ....**Court 0571**

Sinclair, Carroll Taylor (**Associate**) (Dec. 1926) Elec. Engineer, Transmission & Distribution, Pittsburgh Branch, Byllesby Engrg. & Management Corp, 435 Sixth Ave; h, 5457 Bartlett St, Pittsburgh, Pa.................................... **Grant 5750-Ext. 544**

Singer, G. Harton (Sept. 1880) h, R. D. No. 3, Sewickley, Pa.

Sipe, Charles Allen (March 1926) Industrial Engineer, c/o Y. M. C. A, Coraopolis, Pa.

Sivitz, William I. (June 1929) District Engineer, The Duriron Co. Inc. Dayton, Ohio, 922 Empire Building, Pittsburgh, Pa; h, 1630 Duffield Street, Pittsburgh, Pa............................. **Atlantic 4149**

★**SKINKLE, WILLIAM BALDWIN** (**Director**) (July 1910) Engineer, Pittsburgh District Power Committee, Subsidiary Companies of United States Steel Corporation, 1228 Frick Bldg, Pittsburgh, Pa; h, 912 Ridge Ave, Coraopolis, Pa........................ **Atlantic 1300**

Skinner, Charles Edward (Nov. 1903) Asst. Director of Engineering, Westinghouse Elec & Mfg. Co, East Pittsburgh, Pa; h, Elmore Road, Wilkinsburg, Pittsburgh, Pa................... **Brandywine 1500**

Skinner, Orville Campbell (Dec. 1896) Works Mgr, Standard Steel Works Co; h, "Open Hearth," Burnham, Pa.

Slater, Homer B. (May 1920) Engr, The Koppers Construction Co, Koppers Bldg; h, 2922 Glenmore Ave, S. H. Branch, Pittsburgh, Pa.. **Atlantic 6240**

Sleeman, Earl Carlton (Feb. 1913) Chief Engineer, Detroit Seamless Steel Tube Co, West Warren and Wyoming Avenues, Detroit, Michigan; h, 7106 Kingsley Avenue, Fordson P. O, Dearborn, Michigan.

Slocum, Roy L. (May 1917) Asst. Supt, Pittsburgh Plant, Universal Atlas Cement Co, Universal, Pa; h, 1120 Lancaster St, Pittsburgh, Pa. .... **Unity 8**

Sloman, Morley S. (May 1923) Sales Engr, Sullivan Machinery Co, 518 Farmers Bank Bldg; h, 1812 Morrell St, N. S. Pittsburgh, Pa... .... **Atlantic 2792**

Smerling, Carl (**Associate Member**) (March 1928) Engineering Sales & Contracting, Oliver Bldg; h, 804 East End Avenue, Pittsburgh, Pa.. **Atlantic 2718**

Smith, Albert (**Associate Member**) (Dec. 1927) Mining Engr, Graff Interests, Blairsville, Pa; h, Saltsburg, Pa.

Smith, August C. (June 1912) Supt, Frank H. Robinson Inc, 918-20 Behan St, N. S. Pittsburgh, Pa; h, 35 S. Howard St, Bellevue, Pittsburgh, Pa.. **Cedar 8140**

Smith, Cameron C. (Nov. 1899; July 1907) h, West Lake Road, Dunkirk, New York.

Smith, DuRay (Dec. 1927) Supt, Union Spring & Mfg. Co, New Kensington, Pa.

Smith, Harold Whitmore (Dec. 1924) Sales Mgr, Generating Apparatus, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa: h, 510 Pitt St, Wilkinsburg, Pittsburgh, Pa.................... **Brandywine 1500**

Smith, Howard Wells (Dec. 1920) Chief Engr, The Aetna Standard Engineering Co, Youngstown, Ohio; h, Box 545, Ellwood City, Pa.

Smith, Hubert P. (Jan. 1914) Director of Rates, Duquesne Light Co, 435 Sixth Ave, Pittsburgh, Pa; h, 145 Allegheny Ave, Emsworth, Pa... **Grant 4300**

Smith, I. L. (**Student Junior**) (Dec. 1926) Student, West Virginia University; h, 665 Spruce St, Morgantown, W. Va.

Smith, J. Hammond (Nov. 1903) Professor Civil Engineering, University of Pittsburgh; h, 6363 Douglas St, Squirrel Hill Sta, Pittsburgh, Pa.. **Mayflower 3500**

Smith, John Hayes (May 1902; April 1922) Consulting Engineer, Harrisburg, Pa; h, 2609 Market St, Camp Hill, Pa.

Smith, Newton Guy (July 1916) Engr, Contracting Dept, Fort Pitt Bridge Works, Oliver Bldg, Pittsburgh, Pa; h, 44 Oakwood Road, Crafton, Pittsburgh, Pa.................................. **Atlantic 0654**

Smith, Peter Marshall (Oct. 1919) Dist. Mgr, Treadwell Engineering Co 508 Farmers Bank Bldg; h, 101 Lawncroft Ave, Mt. Lebanon, Pittsburgh, Pa.................................. **Atlantic 2833**

Smith, Russell (May 1911) Mech. Supt, Pressed Steel Car Co, Farmers Bank Bldg; h, 19 N. Bryant Ave, Bellevue, Pittsburgh, Pa...... .... **Federal 0740**

Smith, Thomas Walter (Jan. 1909) Structural Engr, Carnegie Steel Co 71 Broadway, New York, N. Y; h, 150 Sylvan St, Rutherford, N. J.

Smith, William, Sr. (Oct. 1902) Supt. of Maintenance, Copperweld Steel Co, 9th & Allegheny Ave, Glassport, Pa; h, 316 Monongahela Ave, McKeesport P. O, Otto, Pa.

Smith, William Wylie (April 1921) Civil and Mining Engineer, Homestead Boro Engineer, Carnegie Gas Company, 336 E. Eleventh Avenue, Homestead, Pa............................ **Homestead 2231-J**

Smith-Peterson, N. O. (June 1923) Superintendent, Works, Sikorsky Aviation Corporation, Stratford, Conn; h, 80 Buena Vista Road, Bridgeport, Conn.

Smitmans, John A. (Dec. 1910; July 1912) Address Unknown.

Smoot, Charles H. (Jan. 1925) Pres. & Treas, Smoot Engineering Corp, 136 Liberty St, New York, N. Y; h, 40 Mountain Ave, Maplewood, N. J.

Smyers, William H. (Sept. 1926) Supervisor of Tests, Duquesne Slag Products Co, 804 Diamond Bank Bldg, Pittsburgh, Pa; h, 817 Freeport Road, New Kensington, Pa................ **Atlantic 3841**

Snowden, Francis Laird, Jr. (Sept. 1915) Engineer, 153 Park Avenue, Saranac Lake, N. Y.

Snyder, John Caspar (Associate Member) (May 1921) Salesman, Electric Controller & Mfg. Co, 1539 Oliver Bldg; h, 1901 Ovid St, Westwood, Crafton, Pittsburgh, Pa.................... **Atlantic 4014**

Snyder, Lester Charles (Junior) (Nov. 1921) Chief Clerk, Fabricating Div, Jones & Laughlin Steel Corp, 3rd & Ross Sts; h, 704 N. Braddock Ave, Pittsburgh, Pa...................... **Court 3240-231**

Sommerfield, E. M. (Junior) (Jan. 1929) Jr. Engr, P. & L. E. R. R., 818 House Bldg; h, 765 Greenfield Ave, Pittsburgh Pa..... **Court 3201**

Southard, Claude Frederic (Oct. 1922) Gen. Mgr, Duquesne Coal & Coke Co, 347 Oliver Bldg; h, 21 Main Entrance Drive, Lebanon Hills, Mt. Lebanon, Pittsburgh, Pa.................... **Atlantic 0902**

Southward, G. B. (April 1922) Mechanization Engr, American Mining Congress, 841 Munsey Bldg, Washington, D. C; h, The Fairfax, 2100 Massachusetts Ave, N. W, Washington, D. C.

Spain, Batt L. (March 1924) Mgr. Compressor Sales, River Works, General Electric Co, West Lynn, Mass; h, 87 Banks Road, Swampscott, Mass.

Speaker, Jay C. (April 1929) Contractor, J. C. Speaker, Commonwealth Annex; h, 454 Marlin Drive, Mt. Lebanon, Pittsburgh, Pa **Court 1937**

Speer, J. Ramsey (June 1918) Pres. American Adamite Co, Point Bldg, Pittsburgh; h, Wilderness Farms, Trappe, Talbot Co, Md. **Court 3862**

★**Speller, Frank Newman** (March 1906) Director Metallurgy & Research Dept, National Tube Co, 1810 Frick Bldg; h, 6411 Darlington Road, E. E, Pittsburgh, Pa........................ **Atlantic 2500**

★**SPELLMIRE, WALTER B. (Past President 1925)** (April 1917) Mgr, General Electric Co, 1309 Oliver Bldg; h, 5701 Solway St, Squirrel Hill Sta, Pittsburgh, Pa.......................... **Atlantic 6400**

Spencer, Elbert Roy (May 1919) Dist. Mgr, The Defiance Motor Truck Co; h. 828 E. Shiawassee St, Lansing, Mich.

Spencer, Howard F. (Junior) (Jan. 1926) Cadet Engineer, The Rust Engineering Co, Koppers Bldg; h, 420 S. Lang Ave, Pittsburgh, Pa. .... **Atlantic 8870**

Spilker, Henry P. (July 1907) Pres, Sterritt-Thomas Fdry. Co, 32nd & Smallman Sts; h, 1617 Jancey St, E. E, Pittsburgh, Pa.. **Atlantic 6790**

Splane, Joshua G. (Dec. 1899) V. P, Detroit Insulated Wire Co, Wesson Ave. & Albert St; h, 439 E. Columbia St, Detroit, Mich.

Sprague, Norman Salisburg (April 1908; Jan. 1925) Consulting Engr, Private Practice, 1011 Bessemer Bldg; h, 6372 Jackson St, E. E, Pittsburgh, Pa................................. **Atlantic 9518**

Sprecher, Clay (May 1905; March 1914) Sales Engr, 1409 Oliver Bldg; h, 5 Highland Court, Callowhill St, Pittsburgh, Pa....... **Atlantic 2014**

Sproull, C. W. (Jan. 1925) Engineer, Union Switch & Signal Co, Swissvale, Pa; h, 113 Washington St, Edgewood, Pittsburgh, Pa. **Penhurst 0880**

Staege, Stephen A. (Jan. 1928) Industrial Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 6624 Beacon St, Pittsburgh, Pa. .... **Brandywine 1500-Ext. 9388**

Stafford, Samuel A. (March 1928) Metallurgical Dept, Vulcan Crucible Steel Co, Aliquippa, Pa; h, 303 Chestnut Road, Edgeworth, Sewickley, Pa................................ **Aliquippa 395**

Stafford, Samuel G. (April 1893) Vice Pres. & Gen. Mgr, Vulcan Crucible Steel Co, Aliquippa; h, 911 McIntyre Ave, Coraopolis, Pa.... .... **Aliquippa 395**

★**Stahl, Karl F.** (April 1892) Cons. Chemist, 2318 Wharton St, S. S. h, 839 Chislett St, Pittsburgh, Pa........................ **Hemlock 1173**

Stanton, Charles Beecher (Oct. 1913) Associate Professor, Civil Engineering, Carnegie Institute of Technology; h, 25 Forbes Terrace, Pittsburgh, Pa................................ **Mayflower 2600**

Starr, Arthur B. Jr. (Nov. 1915) Partner, Starr Equipment Co, 1124 Park Bldg, Pittsburgh; h, R. D. No. 2, Coraopolis, Pa..... **Atlantic 1488-9**

Steber, Herman Louis (Junior) (Oct. 1929) Master Mechanic, Lewis Foundry & Machine Company, Groveton, Pa; h, 710 Hiland Avenue, Coraopolis, Pa................................ **Coraopolis 20**

Steidle, Edward (Feb. 1926) Dean, School of Mineral Industries, The Pennsylvania State College, State College, Pa; h, 5535 Hobart St, Pittsburgh, Pa.

Stenerson, Stener (Sept. 1918) Consulting Engineer. Address Unknown.

Stephens, Wesley McKeown (Nov. 1912) Steam Engr, West Penn Power Co, Springdale, Pa; h, Box 227, Highland Ave, Cheswick, Pa.

Steuber, Milton C. (Associate Member) (Jan. 1928) Structural Engineer, The Koppers Construction Company, Koppers Bldg; h, 1027 Macon Avenue, Pittsburgh, Pa.................... **Atlantic 6240**

Stevens, Frank A. (Sept. 1921) Draftsman, The Texas Company, 929 S. Broadway, Los Angeles, Calif; h, 105-A N. Valencia Ave, Alhambra, Cal.

Stevens, Richard Harry (Nov. 1902) 5200 Springlake Way, Baltimore, Md.

Stevens, William Ronald (Junior) (Sept. 1929) Designer, McClintic-Marshall Co. Engineering Dept, Oliver Bldg; h, Y. M. C. A, 3rd and Wood Sts, Pittsburgh, Pa........................ **Atlantic 2562**

Stevenson, Barton (Oct. 1924) Mgr, Central Station Division, Westinghouse Elec. & Mfg. Co, Grant Bldg; h, 5714 Elgin Ave, Pittsburgh, Pa. .... **Atlantic 8400**

Stevenson, Harry Willis (Jan. 1904) Chf. Engineer, Nadine Pumping Station, Pennsylvania Water Co; h, Nadine, Pa, R. F. D. No. 1, Verona, Pa................................ **Hiland 3063**

Stevenson, John Dickson (Jan. 1910) Chief Engr, Bureau of Bridges and Structures, 335 City-County Bldg; h, 1400 N. Highland Ave, Pittsburgh, Pa. . . . . **Atlantic 3900**

Stevenson, Paul V. (Sept. 1906) Res. Mgr, Morse Chain Co, Westinghouse Bldg; h, 7124 Meade St, Pittsburgh, Pa. . . . . **Grant 7290**

Stevenson, Wilbur W. (Oct. 1924) Steam Heating Engr, Allegheny County Steam Heating Co, 435-6th Ave; h, 1125 Lancaster Ave, Regent Square, Pittsburgh, Pa. . . . . **Grant 4300**

Stewart, Arthur Jackson (June 1929) Assistant Superintendent, United States Aluminum Company, New Kensington, Pa; h, 359 Main Street, Parnassus, Pa. . . . . **New Kensington 8**

Stewart, Jame Ernest (June 1927) Hydraulic Engr, West Penn Power Co. 14 Wood St; h, 600 Highland Place, Bellevue, Pittsburgh, Pa. . . . . **Court 4106**

★**Stewart, Reid T.** (Dec. 1894) Prof. Mech. Engrg, University of Pittsburgh; h, 1524 Shady Ave, Pittsburgh, Pa. . . . . **Mayflower 3500**

Stickle, Edward S. (April 1929) President, E. S. Stickle Company, 953 Union Trust Bldg; h, 5539 Fair Oaks St, Pittsburgh, Pa. **Atlantic 5056**

Stiefel, R. C. (April 1915) Engr, Ellwood City, Pa. . . . . **Ellwood City 81**

Stockdale, Henry S. (Sept. 1923) Sales Engineer, 337 Oliver Bldg; h, 1467 Kelton Avenue, Dormont, Pittsburgh, Pa. . . . . **Atlantic 1504**

★**Stoltz, Glenn E.** (Dec. 1919) Mgr. Industrial Engineering Dept. Westhouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 151 W. Hutchinson Ave, Edgewood, Pittsburgh, Pa. . . . . **Brandywine 1500**

Stone, Carleton Elijah (April 1921) Aires, Stone & Pettay, 335 Blvd. of Allies, Pittsburgh, Pa; h, 702 Main St, Coraopolis, Pa. . . . **Court 0128**

Stone, Edmund Cushing (Oct. 1922) System Development Mgr, Duquesne Light Co, 435-6th Ave; h, 5523 Ellsworth Ave, Pittsburgh, Pa. . . . . **Grant 4300-Ext. 588**

Stone, Lauson (Dec. 1921) Asst. to the Pres, Jones & Laughlin Steel Corp, 1109 J. & L. Bldg, Pittsburgh, Pa; h, 734 Fourth St, Beaver, Pa. . . . . **Court 3240-Ext. 33**

Stone, Richard H. (Nov. 1925) Chief Engineer, The Vesuvius Crucible Co, Palmer Street, Swissvale, Pa; h, 1222 Lancaster Avenue, Swissvale Station, Pittsburgh, Pa. . . . . **Brandywine 0107**

★**Storer, Norman W.** (April 1902) Consulting Railway Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 6818 Reynolds St, Pittsburgh, Pa. . . . . **Brandywine 1500**

Stotz, Edward Jr. (March 1922) Structural Engr, Edward Stotz, Architect, 801 Bessemer Bldg; h, 292 West Prospect Ave, Crafton P. O, Pittsburgh, Pa. . . . . **Atlantic 1153**

Stotz, Norman I. (Associate) (Dec. 1927) Genl. Supt, Braeburn Alloy Steel Co, Braeburn, Pa; h, 426 Tenth St, Oakmont, Pa. . . . **Tarentum 690**

Stow, Frederick Stevens (**Associate Member**) (March 1929) Asst. Engr, The J. N. Chester, Engineers, 813 Clark Bldg, Pittsburgh, Pa; h, 7411 Church Avenue, Ben Avon, Pittsburgh, Pa...... **Atlantic 1140**

Stratton, William Cowper (Sept. 1910) Chf. Engr. United States Coal & Coke Co, Gary, McDowell Co, W. Va.

Straub, Donald Benno (**Junior**) (Jan. 1929) Drafting Dept, Fort Pitt Bridge Works, Canonsburg, Pa; h, 1120 Harvard Rd, Crafton Branch, P. O, Pittsburgh, Pa.................. **Canonsburg 27**

Straub, Theodore Alfred (July 1910) Pres, Electric Welding Co, 311 Ross St, Pittsburgh, Pa; h, 132 W. College St, Canonsburg, Pa.... **Court 2941**

Strickler, J. Harold (June 1924) Dist. Sales Manager, Elliott Company, 718 Frick Bldg; h, 692 Florida Ave, Mt. Lebanon, Pittsburgh, Pa.. **Atlantic 5000**

Stroh, Charles Kirk (June 1928) Sanitary and Hydraulic Engr, The J. N. Chester Engineers, 813 Clark Bldg, Pittsburgh, Pa; h, 710 Beaver St, Sewickley, Pa................................ **Atlantic 1140**

Strong, Carlton (Feb. 1925) Architect, Keystone Bldg; 324 Fifth Ave; h, 4731 Bayard Street, Shadyside, E. E, Pittsburgh, Pa.... **Court 0965**

Stroup, Earle Clifford (Dec. 1927) Compressor Sales Engr, Chicago Pneumatic Tool Co, Room 200, 132 Seventh St; h, 1265 Wisconsin Ave, Dormont, Pittsburgh, Pa.......................... **Atlantic 4286**

★**Stuart, George Johnston** (March 1917) Engineer, Power Piping Society, 1608 Law and Finance Bldg; h, 306 S. Homewood Ave, Pittsburgh, Pa.. **Grant 3434**

Stuart, Gordon W. (**Associate Member**) (Sept. 1926) Div. Supt, Equitable Gas Co, 6404 Penn Ave, Pittsburgh; h, West Waldheim Road, Aspinwall, Pittsburgh, Pa................ **Hiland 6700-Ext. 1528**

Stuckeman, Herman Sydney (**Associate Member**) (May 1921) Union Barge Line Corp, Wabash Bldg; h, 3066 Pinehurst Ave, South Hills Sta, Pittsburgh, Pa................................ **Court 1476**

★**STUCKI, ARNOLD** (**Past President 1915**) (**Treasurer**) (Dec. 1902) Cons. Engr, Oliver Bldg, Pittsburgh, Pa; h, 42 N. Howard Ave, Bellevue, Pittsburgh, Pa.................................. **Atlantic 1250**

Studybaker, Aaron Daniel (June 1928) Bonus Dept, Monongahela Connecting Railroad, 3540 Second Ave; h, 5324 Beeler St, Pittsburgh, Pa.. **Court 3240**

Sturges, Thomas B. (June 1918) President, Pennsylvania Drilling Co, 1812 W. Carson St; h, 3136 Pioneer Ave, Dormont, Pittsburgh, Pa. .... **Walnut 1783**

Sutherland, William Chester (Jan. 1921) Vice-President, In Charge of Manufacturing, Pittsburgh Steel Company, Union Trust Bldg; h, Hampton Hall, 166 N. Dithridge St, Pittsburgh, Pa.... **Atlantic 4760**

Svensson, Otto M. (**Associate**) (Feb. 1925) Engr, Vanadium Corp. of America, h, R. F. D. No. 3, Box 28, Bridgeville, Pa.

Swanberg, Floyd Ludwig (March 1926) Gen. Mgr, Kehota Mining Co, 706 First National Bank Bldg; h, 215 N. Homewood Ave, Pittsburgh, Pa.. **Atlantic 2311**

Swartz, Charles A. (**Associate**) (May 1928) Gen. Sales Mgr, Wilson Snyder Mfg. Co, First & Talbot Ave, Braddock, Pa; h, 1850 Shaw Ave, Pittsburgh, Pa.......................... **Brandywine 2913**

Taber, George H. Jr. (**Associate Member**) (Dec. 1916) V. P, Sinclair Refining Co, 45 Nassau St, New York, N. Y; h, Mendota Ave, Rye, N. Y.

Tafel, Theodore, Jr. (**Associate Member**) (May 1921) c/o Deutsche Standard, GMB H Post 138, Neuss, Germany.

Taggart, R. S. (March 1926) District Engineer, Portland Cement Association, 1707 Koppers Building; h, 214 LeMoyne Ave, Mt. Lebanon, Pittsburgh, Pa................................ **Atlantic 1450**

★**Tanner, J. Roy** (Sept. 1913) 335 Oliver Building; h, 5620 Elgin Avenue, Pittsburgh, Pa................................ **Atlantic 9390**

Taub, Edward S. (June 1925) Senior Engr, Morris Knowles Inc, 507 Westinghouse Bldg; h, Virginia & Zara Sts, Mt. Oliver Sta, Pittsburgh, Pa.. **Atlantic 3882**

Taylerson, Ewart Stanley (June 1924) Engr. of Tests, American Sheet & Tin Plate Co, 320 Frick Bldg; h, 733 Gallion Ave, South Hills, Pittsburgh, Pa. .... **Atlantic 1300**

Taylor, Charles Edward (May 1908) Civil & Mining Engineer, 5715 Solway St, Pittsburgh, Pa............................ **Schenley 0929**

Taylor, Clyde (April 1906) Sales Engineer, Jones & Laughlin Steel Corp, J. & L. Bldg, 311 Ross Street; h, 1431 Mervin Avenue, Dormont, Pittsburgh, Pa................................ **Court 3240**

Taylor, David Edwin (May 1924) Mining Engr; h, Freeport, Pa....... .... **Freeport 207**

Taylor, Ernest Succop (Sept. 1922) Chief Engr, Pittsburgh Coal Co, 1012 Oliver Bldg; h, 5400 Darlington Road, Pittsburgh, Pa....... .... **Atlantic 2181**

Taylor, Harold Alexander (**Associate Member**) (Nov. 1914) Pres, Taylor-Meyer Co, 1401 Keystone Bank Bldg; h, 7123 Meade St, Pittsburgh, Pa.. **Court 3195**

Taylor, Norman C. (**Associate Member**) (April 1924) Draftsman, Montour Railroad Co, 1711 State Ave, Coraopolis, Pa; h, 9 Stanwood St, Crafton, Pittsburgh, Pa....................... **Coraopolis 72**

★**TAYLOR, SAMUEL ALFRED** (**Past President 1913**) (Jan. 1898) Consulting Engineer, Various Companies, 711 First National Bank Bldg; h, 617 Whitney Ave, Wilkinsburg, Pittsburgh, Pa..... **Atlantic 2311**

Templin, Richard Lawrence (**Associate Member**) (Jan. 1920) Chief Engr. of Tests, Aluminum Co. of America, Research Bureau, New Kensington Pa; h, 354 Riverview Drive, Parnassus, Pa. . **New Kensington 8**

Terman, Mark J. (Feb. 1926) Sales Engr. Refractories Dept, Babcock & Wilcox Co, 2730 Koppers Bldg; h, 1501 McFarland Road, Mt. Lebanon, Pittsburgh, Pa. . . . . **Atlantic 0672**

Tew, John B. (Oct. 1927) Boro. Engineer, Baden Borough, P. O. Box 143, Baden, Pa; h, Milton St, Baden, Pa.

Thomas, Edgar A. (June 1924) Construction Foreman, Carnegie Steel Co, Homestead Steel Works, Munhall, Pa; h, Elizabeth, Pa. . . . . **Elizabeth 635-J**

★**Thomas, George P.** (Dec. 1908) Pres. Thomas Spacing Machine Co, 811 Fulton Bldg, Pittsburgh; h, Glenshaw, Pa. . . . . **Atlantic 6459**

Thomas, George W. (Nov. 1924) Chief Engr, H. H. Robertson Co, 2000 Grant Bldg; h, 205 N. Homewood Ave, Pittsburgh, Pa. **Atlantic 3200**

Thomas, Roger F. (**Associate Member**) (May 1927) 11 Audubon Road, Boston, Mass.

Thomas, Roy Emil (June 1929) Sales Manager, Penn Electrical Company, Irwin, Pa; h, 814 Ross Avenue, Wilkinsburg, Pittsburgh, Pa. . . . . **Irwin 83**

★**THOMPSON, ARTHUR WEBSTER** (**Gold Medal 1915**) (March 1915) 1944 Fidelity-Philadelphia Trust Bldg, Philadelphia, Pa.

Thompson, Francis Raymond (**Associate**) (Dec. 1925) Rwy. Engr, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 7531 Tuscarora St, Homewood Sta, Pittsburgh, Pa. . . . . **Brandywine 1500**

★**Thompson, John I.** (Dec. 1919) Vice Pres, The Koppers Construction Co, Koppers Bldg, Pittsburgh, Pa; h, 7070 Woodlawn Ave, Ben Avon, Pittsburgh, Pa. . . . . **Atlantic 6240**

Thorn, Thomas Holmes (Jan. 1920) Asst. Engr, The Chaplin Fulton Mfg. Co, 36 Penn Ave; h, 120 Carnegie Place, Pittsburgh, Pa. . **Court 1201**

Thorne, John Mueller (April 1926) Asst. to Works Mgr, Westinghouse Air Brake Co, Wilmerding, Pa; h, 138 Oakview Ave, Edgewood, Pittsburgh, Pa. . . . . **Brandywine 1490**

Throm, Joseph H. (July 1917) Pgh. Mgr, David Lupton's Sons Co, 1624 Grant Bldg; h, 932 Jancey St, Pittsburgh, Pa. . . . . . . **Atlantic 1814**

★**Tiemann, Hugh P.** (June 1911) Asst. Metallurgical Engr, Carnegie Steel Co, 563 Frick Bldg. Annex, Pittsburgh, Pa. . . . . **Atlantic 5100**

Tishlarich, Ottmar M. (June 1927) Engr, A. M. Byers Company, 6th & Bingham Sts, S. S, Pittsburgh; h, 230 W. Riverview Ave, Bellevue, Pittsburgh, Pa. . . . . **Hemlock 1161**

Toler, James P. (March 1921) Mech. Engr, Pittsburgh Limestone Co, Johnson Bldg; h, 1206 Albert St, New Castle, Pa. . . . **New Castle 404**

Tone, S. L. (March 1891) h, 5305 Westminster Place, Pittsburgh, Pa. .... **Mayflower 5152**

Toner, Arthur Carlton (June 1917) Washington Manager, Portland Cement Association, 925 National Press Bldg, Washington, D. C; h, 2032 Belmont Road, N. W, Washington, D. C.

Totten, Johns McCleave (April 1924) Engineer, Griscom-Russell Co, 285 Madison Ave, New York City; h, 405 Westminster Avenue, Eliza-Beth, N. J.

Tower, Ellwood S. (Sept. 1927) Engr, American Radiator Co, 310 Second Ave; h, 1411 Wightman St, Pittsburgh, Pa.......... **Court 4055**

Townrow, Frederick Wazney (Oct. 1924) Struct. Engineer, The Koppers Const. Co, Koppers Bldg, Pittsburgh, Pa; h, 115 Smithfield St, Canonsburg, Pa.......... **Atlantic 6240**

Townsend, J. F. (**Associate Member**) (April 1926) Gen. Supt, Forged Steel Wheel Co, Butler, Pa.

★**Tracy, Louis D.** (Dec. 1920) Coal Mining Engr, U. S. Bureau of Mines, 4800 Forbes St; h, 4 Forbes Terrace, Pittsburgh, Pa..... **Mayflower 4500**

Trax, Edward Carey (Oct. 1918) Chemical Engr, Water Dept, Filtration Plant, City of McKeesport; h, 1408 Centennial St, McKeesport, Pa .... **McKeesport 22311**

Trayers, Edward B. (Sept. 1919) Draftsman, National Tube Co, McKeesport, Pa; h, 515 Pearl St, Duquesne, Pa.......... **McKeesport 21174**

Tredway, Alexander C. (**Associate Member**) (Dec. 1926) Designing Draftsman, City of Pittsburgh, City-County Bldg; h, 113 Hawkins Ave, N. S, Pittsburgh, Pa.......... **Atlantic 3900-Ext. 191**

Trees, Joe Clifton (April 1924) Arkansas Natural Gas Co, Benedum Trees Bldg; h, Gibsonia, Pa.......... **Court 3765**

TRESCHOW, KENNETH F. (**Secretary**) (March 1924) Secy, Engineers' Society of Western Pennsylvania, William Penn Hotel; h, 1332 Tennessee Ave, Dormont, Pittsburgh, Pa.......... **Atlantic 9392**

Trexler, Edwin W. (Oct. 1921) Supt. Mechanical Dept, Bethlehem Steel Co; h, 514 Luzerne St, Johnstown, Pa.

Trimble, Alexander F. (Nov. 1922) Construction Engr, W. F. Trimble & Sons Co, General Contractors, 1719 Pennsylvania Ave. N. S; h, 82 N. Harrison Ave, Bellevue Branch, Pittsburgh, Pa..... **Cedar 3280**

Trimble, John L. (**Associate Member**) (March 1926) Field Engr, Philadelphia Co, 435 Sixth Ave; h, 616 Copeland St, Pittsburgh, Pa.......... **Grant 4300-Ext. 550**

Trimble, Robert (Jan. 1880) Asst. Chief Engr, Pennsylvania R. R, Pennsylvania Station, Pittsburgh, Pa; h, Sewickley, Pa.......... **Grant 6000-Ext. 90**

★**Trinks, C. L. W.** (March 1901) Professor Mechanical Engineering, Carnegie Institute of Technology; h, 1410 Denniston St, Pittsburgh, Pa. .... **Mayflower 8946**

Truax, J. Charlton (March 1928) Sales Engr, Bertrand P. Tracy Co, 919 Fulton St, N. S; h, 1109 Arch St, N. S, Pittsburgh, Pa. **Fairfax 6536**

Truebe, Paul G. (Oct. 1923) Mech. Engineer, Gibsonia, Pa.

Turnbull, Thomas, Jr. (Oct. 1913) 835 Western Ave, N. S, Pittsburgh, Pa. .... **Fairfax 0452**

Turner, Arthur Arnold (June 1923) Sales Dept, Harbison-Walker Refractories Co, Farmers Bank Bldg; h, 231 Birch Ave, Mt. Lebanon, Pittsburgh, Pa................................ **Atlantic 0942**

Turner, George Walter (Associate Member) (May 1929) Checker, Pittsburgh-Des Moines Steel Company, Neville Island, Pittsburgh, Pa; h, 629 George Street, Coraopolis, Pa................ **Federal 3000**

Tylee, Don O. (Dec. 1923) Steam Specialist, Westinghouse Elec. & Mfg. Co, Grant Bldg, Pittsburgh, Pa; h, 223 Garland St, Edgewood, Pittsburgh, Pa................................ **Atlantic 8400**

Tyler, Lewis P. (Jan. 1919) Technical Mgr, Pittsburgh Branch, Vacuum Oil Co, 717 Clark Bldg; h, 1317 Macon Ave, Pittsburgh, Pa...... .... **Atlantic 8370**

Uhl, Elmer Jerry (Nov. 1919) Owner, Uhl Construction Co, 115 W. 5th Ave, Homestead, Pa; h, 156 Oakview Ave, Edgewood, Pittsburgh, Pa................................ **Homestead 1206**

Uhlinger, Roy H. (Oct. 1924) Chemical Engr, R. H. Uhlinger Laboratories, 2020 W. Liberty Ave; h, 462 Kenmont Ave, Mt. Lebanon, Pittsburgh, Pa................................ **Lehigh 4227**

Umstead, Elgie James (Jan. 1927) Div. Supt, Bureau of Water, City of Pittsburgh, 312 City-County Bldg; h, 2375 Fremont Place, Pittsburgh, Pa................................ **Atlantic 3900**

Undercoffler, William C. (March 1925) Works Mgr, Wyckoff Drawn Steel Co; h, 915 Maplewood Ave, Ambridge, Pa............ **Ambridge 446**

Unger, John S. (Feb. 1896) Mgr, Research Bureau, Carnegie Steel Co, 1054 Frick Bldg. Annex; h, 5538 Aylesboro Ave, Pittsburgh, Pa....... .... **Atlantic 5100**

Unrue, Albert (Dec. 1928) h, 2107 Perrysville Ave, Observatory Branch Pittsburgh, Pa.

Uptegraff, R. E. (June 1918; March 1924) Partner, Rutherford & Uptegraff, 1414 Clark Bldg, Pittsburgh, Pa; h, 1336 Penn Ave, Wilkinsburg, Pittsburgh, Pa............................ **Atlantic 9855**

Urquhart, George Copeland (May 1893) General Agent, Real Estate Dept, Pennsylvania R. R. Co, 512 Pennsylvania Station; h, 431 S. Atlantic Ave, E. E, Pittsburgh, Pa.................. **Grant 6000-Ext. 300**

★**VanDeventer, Frank M.** (Dec. 1920) Mech. Engr, Construction Dept, Henry L. Doherty & Co, 60 Wall St, New York, N. Y; h, 645 St. Marks Ave, Westfield, N. J.

Van Es, Joseph Henry (Junior) (Oct. 1927) Salesman, Edison Lamp Works, General Electric Co, Oliver Bldg; h, Wilson Arms, 549 Neville St, Pittsburgh, Pa .... **Atlantic 6400**

Van Pelt, Arthur A. (Feb. 1925) Sales Engr, Norma Hoffman Bearings Corp; h, 124 Virginia Ave, Aspinwall, Pittsburgh, Pa .. **Sterling 1933**

Van Sickel, Edward L. (Associate Member) (Dec. 1928) Superintendent, W. T. Grange Construction Co, 803 Keenan Bldg; h, 3596 Beechwood Blvd, Pittsburgh, Pa .... **Atlantic 5754**

Venable, William Mayo (Nov. 1913) Mgr, Development Dept, Blaw-Knox Co, P. O. Box 915, Pittsburgh Pa; h, 822 N. St. Clair St, Pittsburgh, Pa .... **Sterling 2700**

★**Vincent, Lewis** (May 1907) Vice-President and Chief Engr, Penn Bridge Co. of America, Beaver Falls, Pa; h, 255 Beaver St, Beaver, Pa. .... **Beaver Falls 656**

Voelker, Aloys A. (Oct. 1914; June 1924) Structural Engr, The Koppers Co, 950 Koppers Bldg; h, 704 Clinton Avenue, Bellevue, Pittsburgh, Pa .... **Atlantic 6240**

Vogel, Leo J. (March 1929) Contracting Engr, Interstate Equipment Corp, 501 Columbia Bank Bldg; h, 286 Magnolia Place, Mt. Lebanon, Pittsburgh, Pa .... **Court 2876**

Vollkommer, Josef (June 1905) Pres. & Gen. Mgr, Vitro Mfg. Co, 60 Oliffe St; h, 230 N. Fairmount St, Pittsburgh, Pa .... **Federal 3550**

Von Thaden, Herbert (June 1929) Vice-Pres. and Gen. Mgr, Pittsburgh Metal Airplane Company, 1625 Island Ave, N. S; h, 312 McCully St, Mt. Lebanon, Pittsburgh, Pa .... **Atlantic 0816**

Wadsworth, Frank L. O. (Nov. 1899) Consulting Engineer, Box 5093 East Liberty Station; h, 340 S. Highland Ave, Pittsburgh, Pa .... **Montrose 1511**

Wagenseil, Edgar W. (Nov. 1927) Sales Engr, Blaw-Knox Co, P. O. Box 915, Pittsburgh, Pa; h, 403 California Ave, Oakmont, Pa .. **Sterling 2700**

Waggoner, Russell E. (Oct. 1901) Manager, Morewood Gardens, Inc, 1060 Morewood Ave, Pittsburgh, Pa .... **Schenley 2457**

★**Waldorf, Fred** (Sept. 1926) Dist. Mgr, Steel Mill Div, Timken Roller Bearing Co, 4925 Liberty Ave; h, 119 Gould Ave, N. S. Pittsburgh Pa .... **Mayflower 7200**

Waldschmidt, Howard Conrad (Associate Member) (Oct. 1927) Electrical Contractor, Glenfield, Pa; h, 360 Kilbuck St, Glenfield, Pa .... **Sewickley 1079-R**

WALES, SAMUEL SIGOURNEY, (**Chairman Steel Works Section**) (April 1925) Chief Elec. Engr, Carnegie Steel Co, 1106 Carnegie Bldg; h, 471 S. Atlantic Ave, E. E. Pittsburgh, Pa........**Atlantic 5100**

Walker, George J. (**Associate Member**) (May 1921) Contracting Engr, Heyl & Patterson, Inc, 52 Water St; h, 5729 Holden St, Pittsburgh, Pa..**Court 0753**

Walker, Harry M. (April 1924) Private Practice, Box 393; h, 109 W. Mahoning St, Punxsutawney, Pa............**Punxsutawney 402**

Walker, James Blair (Jan. 1924) Secretary, Heating and Piping Contractors, 715 Magee Bldg; h, 202 Iroquois Apts, Forbes St, Oakland, Pittsburgh, Pa..**Court 2084**

Walker, J. W. (Jan. 1880) Chairman, Board of Directors, Duquesne Slag Products Co, 425 Commercial Trust Bldg, Philadelphia, Pa; h, Devon, Pa.

Wallace, William T. (May 1902) V. P, South American Gulf Oil Co, 21 State St, New York, N. Y; h, 51 Cedar Drive, Great Neck, L. I, N. Y.

Wallace, William W. (March 1926) Sales Engr, Treadwell Construction Co, Midland, Pa; h, 337-4th St, Beaver, Pa..............**Midland 62**

Wallis, William B. (April 1921) Pres, Pittsburgh Electric Furnace Corporation, Foot of 32nd St; h, 6714 McPherson Blvd, Pittsburgh, Pa. ....**Grant 6221**

★**Walter, Bruce** (Feb. 1903) Chf. Engr, City Blast Furnaces, Carnegie Steel Co, Sharpsburg, Pa; h, 716 Sheridan Ave, Pittsburgh, Pa...... ....**Sterling 1503**

Walter, R. Earle (**Associate Member**) (April 1913) Construction Engr, Kentucky Rock Asphalt Co, Marion E. Taylor Bldg, Louisville, Ky; h, 244 S. Millvale Ave, Pittsburgh, Pa.

Walton, J. P. (Dec. 1927) Asst. Engr. of Bridges, Pennsylvania R. R, 1106 Penna. Station; h, 161 Oakview Ave, Edgewood, Pittsburgh, Pa..**Grant 6000**

Walworth, Stanley L (**Associate**) (Dec. 1926) Dist. Sales Mgr, Ohio Brass Co, 2044 Oliver Bldg, Pittsburgh, Pa; h, 7007 Flaccus Road, Ben Avon, Pittsburgh, Pa..........................**Atlantic 1727**

Ward, Norman Brewer (March 1928) Mgr. Bond Dept, Peoples Pittsburgh Trust Co, 4th Ave. & Wood St; h, 20 Canterbury Road, Ben Avon, Pittsburgh, Pa.........................**Court 5600**

Warden, William G. (Sept. 1925) Chariman of Board, Pittsburgh Coal Co, 1131 Oliver Bldg, Pittsburgh, Pa; h, "Red Gate" School Lane, Germantown, Philadelphia, Pa...................**Atlantic 2181**

Warner, James Paul (Oct. 1925) Electrical Engr, Private Practice, 903 Century Bldg; h, 5350 Beeler St, Pittsburgh, Pa......**Atlantic 2679**

Warren, George S. (Oct. 1911) Chf. Engr, Sharon Steel Hoop Co, h, 936 Alcoma St, Sharon, Pa..........................**Sharon 1910**

Warren, Ray V. (May 1929) Engineering Representative, Western Penna. Sand & Gravel Association, 409 Empire Building, Pittsburgh, Pa; h, 636 Orchard Avenue, Bellevue, Pittsburgh, Pa. . . . **Atlantic 6348**

Waterman, Fred W., Sr. (March 1929) President, National Tube Co, Frick Building; h, Schenley Apts, Pittsburgh, Pa. . . . . **Atlantic 2504**

Watson, Thomas Paul (Oct. 1925) Prin. Asst. Engr, Philadelphia Improvement Co, Pennsylvania R. R. Co, Broad St. Sta, Philadelphia, Pa; h, 148 Edgehill Road, Bala, Pa.

Watkins, Donald N. (June 1927) Pres. & Genl. Mgr. Steel Publication, Inc., Thaw Bldg, 108 Smithfield St; h, 1500 Greenmont Ave, Dormont, Pittsburgh, Pa. . . . . **Court 1214**

Watt, Scott Nevin (Sept. 1922) Sales Engineer, American Bridge Co, 1418 Frick Bldg, Pittsburgh, Pa; h, 228 Dalzell Ave, Ben Avon, Pittsburgh, Pa. . . . . **Atlantic 4300**

Watts, Joseph (June 1920) Engineer, Box 219, Salem, Mass.

Weaver, George H. (**Associate Member**) (Sept. 1914) Plant Mgr, The Atlantic Refining Co, 5733 Butler St, Pittsburgh, Pa; h, Highland Terrace, O'Hara Twnshp, Aspinwall, Pittsburgh, Pa. . . . . **Fisk 1361**

Weber, Karl B. (May 1917) Architect, Designer and Engr, City of Pittsburgh, Old City Hall, N. S; h, Montana and Fairbanks Ave, Pittsburgh, Pa. . . . . **Cedar 0168**

★**Webster, T. Frank** (Sept. 1903) Mgr. Sales, Link Belt Co, Philadelphia; h, Cliveden Hall, Germantown, Philadelphia, Pa.

Webster, W. R. (Dec. 1927) Engineer, The Alan Wood Steel Co, Conshohocken, Pa; h, 2333 N. 17th St, Philadelphia, Pa.

★**Weidlein, Edward Ray** (March 1919) Director, Mellon Institute of Industrial Research, University of Pittsburgh, Chemist & Chemical Engr; h, 6549 Northumberland St, Pittsburgh, Pa. . **Mayflower 1100**

Weiland, George C. (April 1928) Secy. & Sales Mgr, Schaffer Poidometer Co, 2818 Smallman St; h, 412 Jucunda St, Pittsburgh, Pa. . . . . **Atlantic 9030**

Weimer, Wilbur G. (April 1921) Section Engr, Philadelphia Co, 435 Sixth Ave, Pittsburgh, Pa; h, 615 Ferree St, Coraopolis, Pa. . . . . **Grant 3200-Ext. 550**

Weir, Ernest T. (Jan. 1921) Pres, Weirton Steel Co, Weirton, W. Va; h, Schenley Apts, Pittsburgh, Pa. . . . . **Mayflower 2044**

Weir, Paul Latimer (**Associate**) (Dec. 1927) Engineer, Byllesby Eng. & Management Corp, 435 Sixth Avenue; h, 445 Franklin Avenue, Wilkinsburg, Pittsburgh, Pa. . . . . **Grant 5750**

Weise, Paul H. (Jan. 1925) Engr, South Fayette Coal Co, 530 Oliver Bldg, Pittsburgh, Pa; h, Fredericktown, Pa.

★**Weldin, Wm. Archie** (May 1903) Member firm, Blum, Weldin & Co, Engineers & Surveyors, 417 Grant St; h, 1938 Beechwood Blvd, Pittsburgh, Pa....................................**Court 4997**

Welker, Richard M. (Jan. 1926) Lubricating Engr, Gulf Refining Co, 1256 Frick Bldg. Annex; h, 675 Washington Road, Mt. Lebanon, Pittsburgh, Pa....................................**Atlantic 5300**

★**Wendt, Edwin Frederick** (April 1892; Jan. 1913) Consulting Engineer, Union Trust Bldg, Washington, D. C; h, 1470-3rd Ave, New Brighton, Pa.

Wessel, Albert H. (Jan. 1928) Chief Engr, Bernard H. Prack, 408 Martin Bldg; h, 1326 Wightman St, Pittsburgh, Pa...........**Fairfax 7841**

Westinghouse, Henry Herman (May 1902) Chairman, Westinghouse Air Brake Co, 150 Broadway, New York, N. Y.

Wharton, Joseph B. (April 1919) Chief Engr, Spang Chalfant & Co, Inc, Ambridge, Pa; h, Box 296, Baden, Pa.............**Ambridge 380**

Wharton, William Bakewell (**Associate Member**) (Sept. 1923) Patent Attorney, Farmers Bank Bldg; h, 1208 Murrayhill Ave, Pittsburgh, Pa...**Atlantic 0386**

Wheeler, William Sprague (Dec. 1928) Vice Pres. & Treas, Pennsylvania Engineering Works, New Castle, Pa; h, 301 Sheridan Ave, New Castle, Pa.

Whigham, William, Jr. (April 1923) Master Mechanic, Clairton By-Products Coke Works, Carnegie Steel Co, Clairton, Pa; h, 659 Delaware Ave, Wilson Sta, Clairton, Pa................**Clairton 5-Ext. 19**

White, Harold E. (Dec. 1924) Control Engrg. Dept, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 1302 Singer Place, Wilkinsburg, Pittsburgh, Pa.................................**Brandywine 1500**

White, Harry M. (June 1928) Mgr. of Mines, Pittsburgh Coal Co, 1018 Oliver Bldg; h, 2922 Belrose Ave, South Hills Sta, Pittsburgh, Pa. ....**Atlantic 2181**

White, Jerome C. (Dec. 1928) Production Engr, Pittsburgh Coal Co, 1012 Oliver Bldg; h, 1416 Potomac Ave, Pittsburgh, Pa...**Atlantic 2181**

Whited, E. Willis (Dec. 1915) Acting Director, Co-Operative Work, University of Pittsburgh, 111 Thaw Hall; h, 7329 McClure Avenue, Swissvale, Pittsburgh, Pa..........................**Mayflower 3500**

Whited, Willis (Jan. 1899) Advisory Bridge Engineer, State Department of Highways, Harrisburg, Pa; h, 26 South 3rd Street, Harrisburg, Pa.

Whiter, Edward Taft (June 1925) Regional V. P., Pennsylvania Railroad Co, 921 Pennsylvania Station; h, Bellefield Dwellings, Pittsburgh, Pa...**Grant 6000-240**

Whitman, Paul Siebert (Nov. 1897) Engr, Riter-Conley Works of the McClintic-Marshall Co, Oliver Bldg; h, 68 W. Prospect Ave, Ingram, Pa...**Atlantic 2562**

Whitewell, George E. (Dec. 1926) Gen. Sales Mgr, Philadelphia Company, 435-6th Ave; h, 1216 Denniston Ave, Pittsburgh, Pa........ ....**Grant 3200-Ext. 212**

Wickerham, Philip Sheridan (Oct. 1925) Consulting Civil Engr, City of Butler, Central Fire Station; h, 339 N. McKean St, Butler, Pa.... ....**Butler 24121**

Wiester, Blanchard Clyde (Associate) (Dec. 1924) Salesman, Bethlehem Steel Co, 1807 Oliver Bldg, Pittsburgh, Pa; h, 1114 Craig St, McKeesport, Pa....................................**Atlantic 1964**

Wiggins, William D. (June 1927) Chief Engr, Central Region, Pennsylvania R. R, 1135 Pennsylvania Station; h, 1128 Princeton Ave, Crafton, Pittsburgh, Pa............................**Grant 6000-Ext. 90**

Wilcox, Frank (Jan. 1894) Engineer, Retired, 533 Fifth Ave, Pittsburgh Pa; h, 214 Thorn St, Sewickley, Pa................**Atlantic 0564**

Wilcoxson, Leslie Swales (Associate Member) (April 1924) Engr, Babcock & Wilcox Co, 85 Liberty St, New York; h, 191 Highwood Ave, Ridgewood, N. J.

★**Wilkerson, T. J.** (April 1903; Jan. 1925) Consulting Engr, Private Practice, Box 444, 721 Eleventh St; h, 3221 Sixth Ave, Beaver Falls, Pa...**Beaver 1450**

Willard, J. O. (Jan. 1925) Civil Engineer, 1232 Franklin Ave, Woodlawn, Pa.

Williams, D. Curtis (May 1921) M. E. National Works, National Tube Co, 2222 Second Ave; h, 664 Maryland Ave, Pittsburgh, Pa..**Grant 1548**

Williams, Frank Way (Associate Member) (May 1926) Sales Engr, Simplex Pile Foundation Co, Conestoga Bldg; h, 5409 Coral St, E. E. Pittsburgh, Pa....................................**Court 2247**

Williams, Harold E. (Dec. 1924) Pres, Williams & Co. Inc, 901 Pennsylvania Ave, N. S; h, 5128 Pembroke Place, Pittsburgh, Pa......**Cedar 2980**

Williams, Homer D. (Jan. 1915) Pres, Pittsburgh Steel Co, P. O. Box 72, 700 Union Trust Bldg; h, Schenley Apts, Pittsburgh, Pa....... ....**Atlantic 4760**

Williams, Howard L. (Sept. 1920) Pres, Pittsburgh Wire Rope Co, Verona Pa; h, 14 Washington Ave, Oakmont, Pa.........**Oakmont 157**

Williams, James Peter, Jr. (May 1925) V. P, The Koppers Coal Co, 1050 Koppers Bldg; h, 621 S. Linden Ave, Pittsburgh, Pa..**Atlantic 6240**

Williams, Marshall (Jan. 1903; March 1916) Asst. Gen. Operating Mgr, American Bridge Co, 1510 Frick Bldg; h, 6105 Howe St, Pittsburgh, Pa..................................**Atlantic 4300**

Williams, Thomas McRae (Junior) (Dec. 1929) Technical Employee, American Telephone & Telegraph Co, 416 Seventh Avenue; h, 1316 Beechview Ave, South Hills, Pittsburgh, Pa...**Official 0050-Ext. 664**

Wills, Felix P. (**Associate**) (March 1928) Power Engineering Dept, Westnghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 921 Ridge Ave, N. S, Pittsburgh, Pa.......................... **Brandywine 1500**

Wilson, Charles A. McKinley (**Associate Member**) (April 1926) Draftsman, Pittsburgh Coal Co, Preparation Department, 8 Market St, Pittsburgh; h, 333 Tioga St, Homestead Park, Homestead, Pa **Court 1877**

Wilson, Dean R. (**Associate Member**) (Feb. 1924) President, Industrial Finance & Investment Co, 829 Oliver Bldg; h, Fox Chapel Manor, Aspinwall, Pittsburgh, Pa.......................... **Atlantic 0840**

Wilson, Edward (April 1928) Sales Engr, Rust Engineering Co, 502 District National Bank Building, Washington, D. C; h, Valley Vista Apt. 315, 2000 Belmont Road, Washington, D. C.

Wilson, Henry Dalzell (July 1921) Clark Bldg, Pittsburgh; h, 1011 Oak Grove Ave, Pasadena, Cal.......................... **Atlantic 0353**

Wilson, Howard M. (**Associate Member**) (Dec. 1926) Secy, Taylor-Wilson Mfg. Co, McKees Rocks, Pa; h, 3150 Avalon St, E. E, Pittsburgh, Pa.. **Federal 0171**

Wilson, Leonard J. (April 1906) Asst. Engr, Brier Hill Steel Co, Youngstown, O; h, R. F. D. No. 2, Warren, O.

Wilson, Robert Lee (May 1905) Asst. to President, Westinghouse Elec. & Mfg. Co, East Pittsburgh, Pa; h, 5744 Kentucky Ave, Pittsburgh, Pa.. **Brandywine 1500**

Winder, Frank Joseph (**Associate Member**) (Nov. 1923) Research Eng. (Supt.) Surface Combustion Company, 2375 Dorr Street, Toledo, Ohio; h, 3428 Brantford Road, Ottawa Hills, Toledo, Ohio.

Winkleman, Edward J. (April 1924) Chief Engineer, Duquesne Slag Products Co, 808 Diamond Bank Bldg, Pittsburgh, Pa; h, 121 Washington Ave, Oakmont, Pa.................... **Atlantic 3841**

Wisecarver Timothy J., Jr. (**Associate**) (March 1929) Salesman, Aluminum Co. of America, 1618 Oliver Bldg: h, Webster Hall, Pittsburgh, Pa. .... **Atlantic 4545**

Wisener, George Edward (June 1916) Gen. Supt, Carnegie Steel Co, Mingo Junction, O; h, 1013 LaBelle Ave, Steubenville, O.

Wishoski, I. Stanley (**Associate Member**) (March 1923) Managing Editor, "Fuels & Furnaces", F. C. Andresen & Associates, Inc, 511 Plaza Bldg, Pittsburgh; h, 313 Pennwood Ave, Wilkinsburg, Pittsburgh, Pa.. **Atlantic 5002**

Witherow, William Porter (Oct. 1910) Pres, Witherow Steel Co, Neville Island; h, 5448 Northumberland Ave, Pittsburgh, Pa.. **Federal 0514**

Witmer, Charles Kenneth (June 1920) M. M. Westmoreland Coal Co; h, Penna. Ave & Locust St, Irwin, Pa.

Witney, William Leslie (Junior) (Jan. 1924) Supervisor of Inspection, South Side Works, Jones & Laughlin Steel Corp; h, 706 College Ave, E. E, Pittsburgh, Pa .... **Hemlock 0401-Ext. 184**

Witt, Charles Victor (Jan. 1907) President, Witt-Humphrey Steel Co, Greensburg, Pa; h, Greensburg, Pa .... **Greensburg 1460**

Wohlgemuth, M. J. (Jan. 1928) Industrial Engineer, Westinghouse Elec. & Mfg. Co, Grant Bldg; h, 1218 Morningside Ave, Pittsburgh, Pa .... **Atlantic 8400**

Wolfe, H. C. (Nov. 1929) Sales Manager, U. S. Chromium Corporation, 1100 Pitt Street, Wilkinsburg, Pa; h, 955 S. Braddock Ave, Pittsburgh, Pa .... **Penhurst 5175**

Wood, Eric Fisher (Oct. 1921) Proprietor Eric Fisher Wood & Company, 233 Oliver Avenue; h, 5848 Solway St, Pittsburgh, Pa .. **Atlantic 4075**

Wood, Frank Joseph (Dec. 1927) Engr, Rolling Mill Dept, Mesta Machine Co, W. Homestead, Pa; h, 431 Layton Avenue, Dormont, Pittsburgh, Pa .... **Homestead 1080**

Wood, Samuel C. (June 1911) Supt, Howard Axle Works, Carnegie Steel Co, Homestead, Pa; h, 1414 Browning Road, E. E, Pittsburgh, Pa .... **Homestead 2603-Ring 4**

Woods, Leonard G. (Jan. 1888) Pres, Union Spring & Mfg. Co, 2001 Clark Bldg; h, Hotel Schenley, Pittsburgh, Pa .... **Atlantic 3060**

★**Wooldridge, Charles Lawson** (April 1906) Consulting Engineer, Charles L. Wooldridge, Inc, 1027 Fulton Bldg; h, 819 St. James St, Pittsburgh, Pa .... **Grant 4025**

Work, William Roth (June 1916; Jan. 1924) Professor, Electrical Engineering, Carnegie Institute of Technology; h, 5702 Beacon St, Pittsburgh, Pa .... **Mayflower 2600**

Worthington, Arthur Whittemore (Dec. 1927) Asst. to Gen. Mgr, Pittsburgh Limestone Co, 216 Carnegie Bldg; h, University Club, 123 University Place, Pittsburgh, Pa .... **Atlantic 5100**

Worthington, Harvey R. (Associate) (May 1924) Real Estate Broker, Harvey R. Worthington Co, 102 Vandergrift Bldg; h, 358 S. Highland Ave, E. E, Pittsburgh, Pa .... **Court 2956**

Wray, David Conden (Dec. 1928) Genl. Supt, American Zinc & Chemical Co, Langeloth, Pa .... **Burgettstown 82**

Wunder, Edgar D. (Nov. 1928) Engr, Pittsburgh Coal Company Shops, Library, Pa; h, 1141 McNeilly Ave, South Hills, Pittsburgh, Pa. .... **Library 52**

Wyant, Frank A. (April 1921) Carnegie Land Co, 357 Frick Bldg; h, 5520 Baum Blvd, E. E, Pittsburgh, Pa .... **Atlantic 5100**

Wyrough, Clement J. (May 1925) Supt, Steam Power Dept, South Side Works, Jones & Laughlin Steel Corp; h, 41 Marlin Drive, E., Mt. Lebanon, Pittsburgh, Pa .... **Hemlock 0401**

Yardley, John Linn McKim (May 1921) Mgr. Engineering Div, Westinghouse Elec. & Mfg. Co, Grant Bldg; h, 901 S. Negley Ave, Pittsburgh, Pa. . . . . **Atlantic 8400**

Yohe, James B. (June 1922) Retired V. P. Pittsburgh & Lake Erie R. R. Co, 106 P. & L. E. Terminal Bldg; h, 87 King Edward Apts Pittsburgh, Pa. . . . . **Court 5524**

Young, Charles A. (**Associate**) (Sept. 1923) Pres. Young Roadbuilders Co, 611 Farmers Bank Bldg, Pittsburgh, Pa; h, 32 Grant Ave, Bellevue, Pittsburgh, Pa. . . . . **Atlantic 2917**

★**Young, Lewis E.** (Feb. 1927) V. P, Pittsburgh Coal Co, 1015 Oliver Bldg, Box 64; h, Bldg. F, Schenley Apts, Pittsburgh, Pa. . . . **Atlantic 2181**

Young, P. Arthur (Sept. 1903; Nov. 1922) Material Inspector, Stone & Webster, Boston, Mass; h, R.F.D. No. 2, Bridgeville, Pa. . . . . **(Pgh. office) Atlantic 3052**

Youngman, Robert Harper (**Associate Member**) (May 1915) Asst. to Pres, Harbison-Walker Refractories Co, 2216 Farmers Bank Bldg; h, 206 S. Linden Ave, Pittsburgh, Pa. . . . . **Atlantic 0942**

Zeeryp, H. C. (**Associate Member**) (Nov. 1923) Dist. Mgr, Otis Elevator Co, 406 Chamber of Commerce Bldg; h, 1222 Lancaster St, Pittsburgh, Pa. . . . . **Atlantic 9292**

Zelditch, Morris (March 1928) Manufacturers' Representative, 212 Fitzsimmons Bldg, 331 Fourth Ave; h, 2301 Lutz Ave, Carrick, Pittsburgh, Pa. . . . . **Court 1852**

Zimmerman, Rufus Eicher (March 1924) Asst. to V. P, American Sheet & Tin Plate Co, 1320 Frick Bldg; h, 300 S. Linden Ave, Pittsburgh, Pa. . . . . **Atlantic 1300**

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Dunsford, J. R.
Millard, E. H.

Elizabeth
Miller, H. R.
Reed, V. A., Jr.
Thomas, E. A.

Ellwood City
Baxter, J. W.
Dunnells, C. G.
Offutt, J. W.
Pugh, G. A.
Smith, H. W.
Stiefel, R. C.

Emsworth
Berger, J. N.
Culler, A. A.
Emrick, A. B.
Forsberg, R. P.
Francies, W. H.
Hazeltine, H. L.
Smith, H. P.

Etna
Ritts, W. H.

Farrell
Rodgers, E. H.

Finleyville
Reese, D. M.

Franklin
Dake, W. M.

Fredericktown
Weise, P. H.

Freeport
Taylor, D. E.

Galina
Kier, S. M.

Glassport
McMullin, P. S.
Smith, W., Sr.

Gibsonia
Truebe, P. G.

Glenfield
Johanson, H. K.
Kratzer, W. N.
Leeper, J. B.
Waldschmidt, H. C.

Glen Osborne
Berg, J. D.
Dann, A. W.
Leonard, J. F.
Marks, H. E.

Glenshaw
Higgins, T.
Thomas, G. P.

Greensboro
Danahy, J.

Greensburg
Comstock, R. A.
Hammer, L. E.
Jamison, W. W.
Lynch, C. F.
Meyer, P. A.
Rudd, H. H.
Witt, C. V.

Greenville
Layng, F. R. S.
Porter, H. T.

Harrisburg
Beckwith, H. E.
Eckels, S.
Hosler, R. N.
Hovey, O. W.
Whited, W.

Haysville
Over, R. W.

Homestead
Schuchman B. F.
Smith, W. W.

Homestead Park
Davis, C. E.
Wilson, C. A. M.

Houston
Geeseman, D. B.

Ingram
Hess, C. E.
Kern, P. D.
Rayburn, J. M.
Whitman, P. S.

Irwin
Hockensmith, W. D.
Miller, J. M.
Perkins, T. S.
Witmer, C. K.

Johnstown
Bracken, M. J.
Brown, H. V.
Johns, T. R.
Trexler, E. W.

Kittanning
Barnes, J. F.
Lloyd, F. J.
Norman, F.

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Cochran, J. S

Langeloth
Wray, D. C.

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Giles, D. J.
McKenna, R. C.

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Kubitz, F.
Le Bon, C. B.
MacLachlan, R.

McKeesport
Butler, T. E.
Clark, M. P.
Cooley, H. M.
Goodspeed, G.M.
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Herrman, T. J.
Hill, F. L.

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McCrystle, J.
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Ottinger, H.
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Trax, E. C.
Wiester, B. C.

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Adair, W. R.

Mather
Dunbar, F. B.

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McInerney, W. I.

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Busch, H. F.
Lyon, J. A.

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Chartener, V., Jr.

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Rodgers, W. P.

Morrisville
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Bohn, D. I.
Boyle, W. W.
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Denigan, E. P.
Elliott, B. K.
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Foight, C. D.
Freeman, P. J.
Gamble, E. R.
Garratt, F.
Grimm, B. F.
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Horner, W. E.
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McCain, P. L.
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Nelson, J. A.
Nichols, G. W.
Nourie, L. R.
Osbourne, R. B.
Olson, H. M.
Orr, N. H.
Orr, R. V.
Orr, T. E.
Overton, R. M.
Palmer, C. D.
Peebles, T. A.
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Rapp, R. L.
Rederer, B. S.
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Schultz, F. G.
Shotton, B. G.
Slater, H. B.
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Wyrough, C. J.

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Clement, A. E.

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Mali, F. F.
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Rowland, R. W.
Toler, J. P.
Wheeler, W. S.

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North Braddock
Phillips, F. B.

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Duden, E. G.
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Stotz, N. I.
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Williams, H. L.
Winkleman, E. J.

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Donald, J. S.
Douglas, H. B.
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Eaton, H. T.
Eavenson, H. N.
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Elliott, W. S.
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Ellman, F.
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Endsley, L. E.

Evans, T. R.
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Fawell, J. E., Jr.
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Ferrara, G. P.
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Fink, S. I.
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Firth, L. G.
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Flanagan, G. E.
Flippen, J. P.
Flynn, F. E.
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Foster, S. D.
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Fownes, W. C., Jr.
Fox, C. L.
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Frank, H. H.
Frank, I. W.
Frank, R. J.
Frank, W. K.
Frauenheim, A. M.
Freeman, A. Y., Jr.
Freund, J. deS.
Frohman, E. D.
Fuller, S. L.
Gallinger, W. N.
Gare, M. S.
Gass, K. W.
Gealy, E. J.
Gerber, C. B
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Gerwig, H. C.
Gill, D. D.
Gillespie, T. J., Jr.
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Goodale, S. L.
Goodwin, W. C.
Gordon, B. T.
Graham, H. W.
Gray, T. W.

Greenberg, M.
Grimes, L. W.D.
Growdon, J. P.
Gunther, F. A.
Guthrie, J. M.
Haines, J. E.
Haines, W. L. R.
Haldeman, J. F.
Hall, W. F.
Haller, H. E.
Hallgren, E.
Hallock, J. W. W.
Hammill, F. W.
Hammond, J. H.
Handloser, B. F.
Hansen J. M.
Hansen, W. C.
Hanst, J. F.
Harris, B. F.
Harshbarger, E. D.
Harvey, C. K.
Haworth, M. E.
Haydock, W.
Heald, K. C.
Hecht, M.
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Heichert, H. S.
Henderson, H.
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Hendrix, W. W.
Henrici, F. W.
Heppenstall, C. W.
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Herr, B. M.
Hertzler, S. P.
Hester, E. A.
Hicks, J. R.
Higgins, R. W.
Hildreth, H. F.
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Hiller, A.
Hinnau, W.
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Holbrook, E. A.
Holland, W. J.
Holleran, M. J.
Hook, C. H.
Hord, P. R.
Horelick, S.
Howell, S. A.

Hower, H. S.
Huff, G. F.
Hufschmidt, A.
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Hunter, E. O.
Hunter, P. E.
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Hutton, F. E.
Iffarth, W. C.
Ingham, F.
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Iversen, L.
Jackman, D. E.
Jackson, J.
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Jacobs, N. B.
James, J. H.
Jarvis, W. R.
Jobke, A. F.
Johnson, J. F.
Jones, A.
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Jones, F. W.
Jones, M. J. H.
Jordan, E. H.
Kaiser, B. J.
Kalbach, W. R.
Karpov, A. V.
Keagy, A. D.
Keebler, H. J.
Keefer, W. W.
Keenan, A. W.
Keller, C.
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Kelley, H. D.
Kelly, J. A.
Kelly, J. M., Jr.
Kemery, P.
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Kennedy, J. W.
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Kerr, B. A.
Kiefer, L. J.
Kintner, S. M.
Kirker, H. L.
Kirkpatrick, G. M.
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Kommer, J. R.
Kramer, F. P.
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Lacock, J. S.
Lagatollo, P. E.
Lahr, R. W.
Lanahan, F. J.
Langstaff, H. A. P.
Larned, J. M.
Lassman, B.
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Laughlin, A.
Lavine, S.
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LeCates, R. H.
Lee, L. R.
Leebov, N.
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Lehman, A. C.
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Leisenring, W. J.
Leland, E. D.
Lewis, H. J.
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Little, W. R.
Lockhart, J. M.
Loeffler, G. O.
Lougee, L. O.
Ludgate, B. A.
Lundgren, E. H.
Luty, B. E. V.
Lyon, D.
McAleenan, G. R.
McClintic, H. H.
McClintock, F. S.
McConnell, M. R.
McCullough, F. M.
McCune, W. H.
McDaniel, B. P.
McElheny, G. B.
McEwen, F. B.
McFarlen, J. P.
McGovern, T. J.
McGrath, M. H.
McIntire, T. B.
McIntyre, L. W.
McKean, R. A.
McKee, F. C.
McKee, W. M.
McKenzie, C. L.
McKinley, J.
McLean, H. A.
McMillen, A. K.
McMillen, R. H.
McMillin, O. B.
McNaugher, D. W.
McNeil, D.
McNiff, G. P.
MacKenzie, J. J. P.
Malady, J. A.
Malevich, V.
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Mantle, G. D.
Marsh, B. W.
Marshall, C. D.
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Martin, J. M.
Mason, J. R.
Matheson, C. P.
Mathieu, H. P.
Medley, H. C.
Meermans, L. H.
Mellsop, C. E.
Menaglia, V. A.
Messler, E. L.
Metzger, W. F.
Meyran, L. A.
Middleton, R. T.
Miller, L. H.
Milliken, J.
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Mirick, A. S.
Mitchell, R. A.
Mitchell, T. J.
Monk, P. S.
Monro, W. L.
Moore, R. W. E.
Moore, W. E.
Morganstern, R. M.
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Morison, G. S.
Morrison, T
Morse, E. K.
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Motok, G. T.
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Mullen, J. L.
Mundo, C. J.
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Murto, H. C., Jr.
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Nagin, H.
Nation, R. B.
Neale, A.
Nelms, G. C.
Newcomer, D. A.
Nicholson, J. H.
Niemann, C. F.
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O'Connor, H. D.
Orr, N. H.
Orssten, T.
Osler, G. F.
Ousler, G. W.
Paddock, L. A.
Palmer, C. K.
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Parkin, W. M.
Parmelee, E. L.
Passmore, H. E.
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Peterson, V. H.
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Provan, J. S.
Provost, G. W.
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Robinson J. F.
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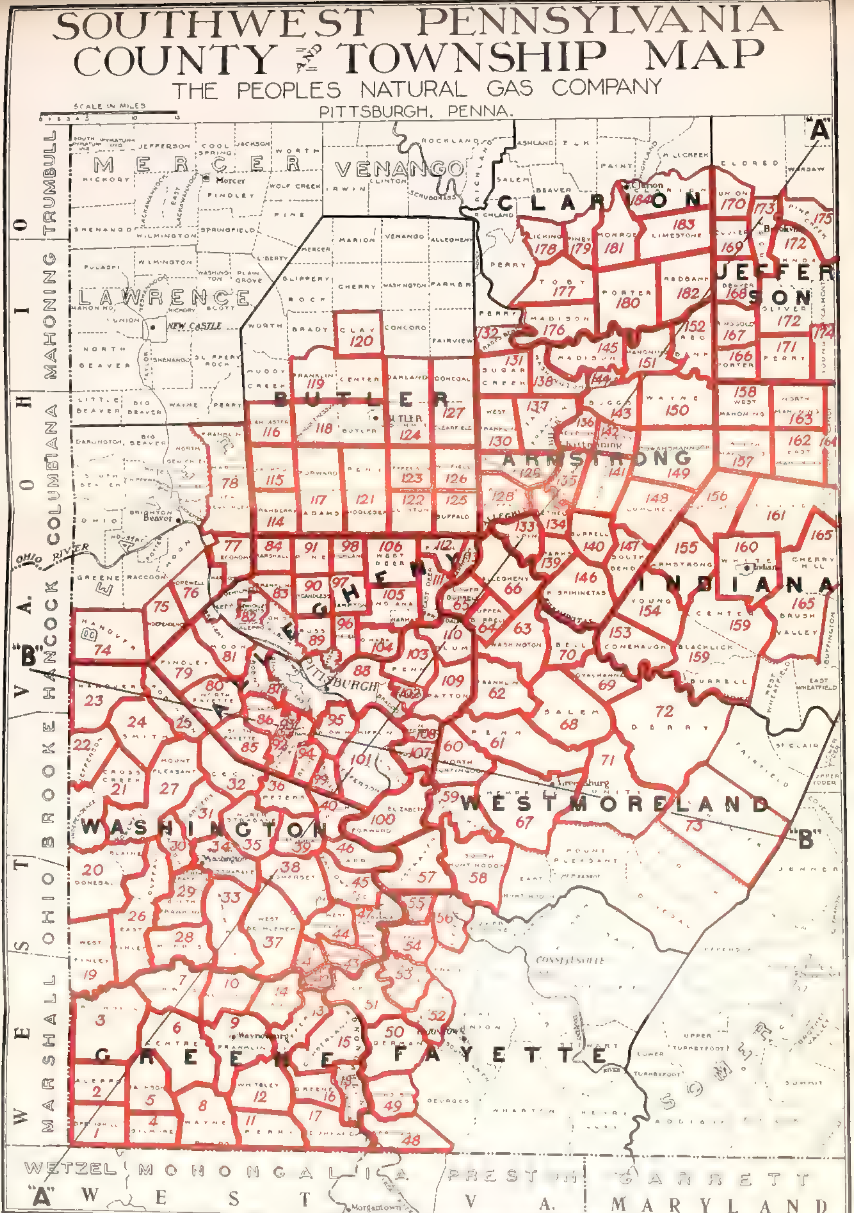


Fig. 1. Outline Map of Southwestern Pennsylvania Showing Location of Type Sections 1 to 184, and of Sections "AA" and "BB".

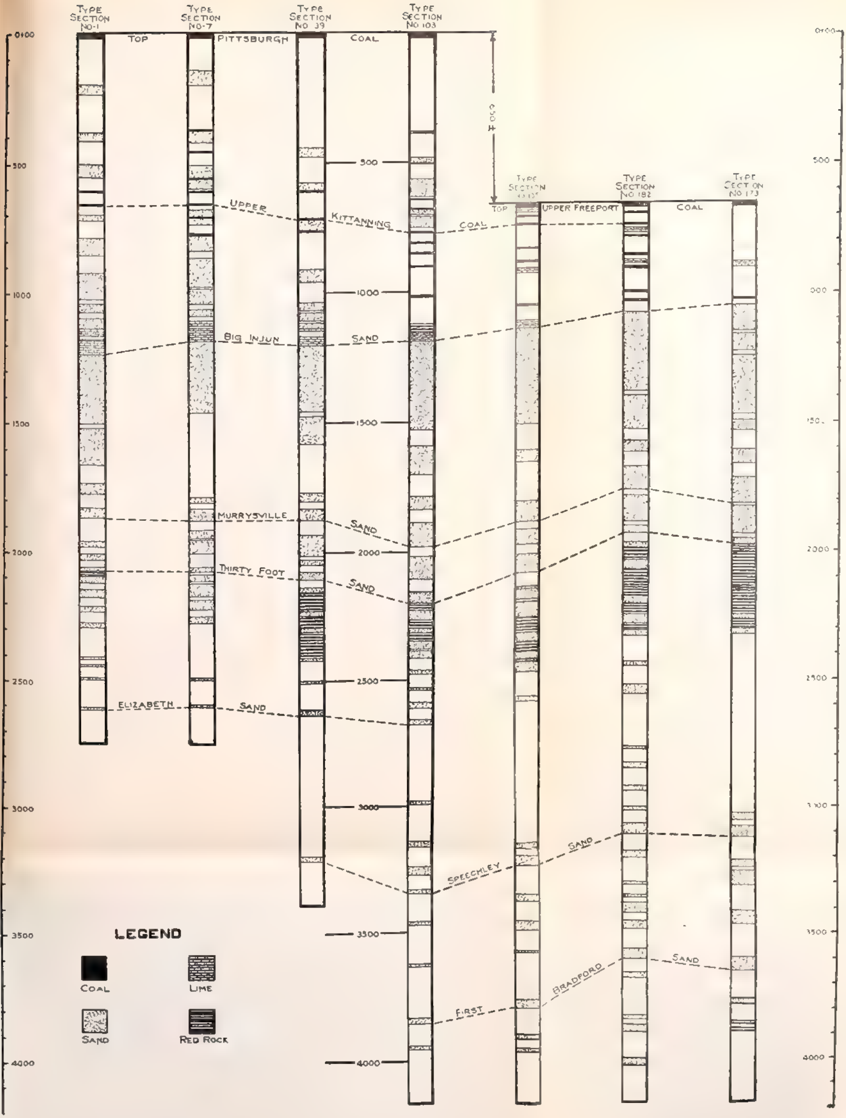
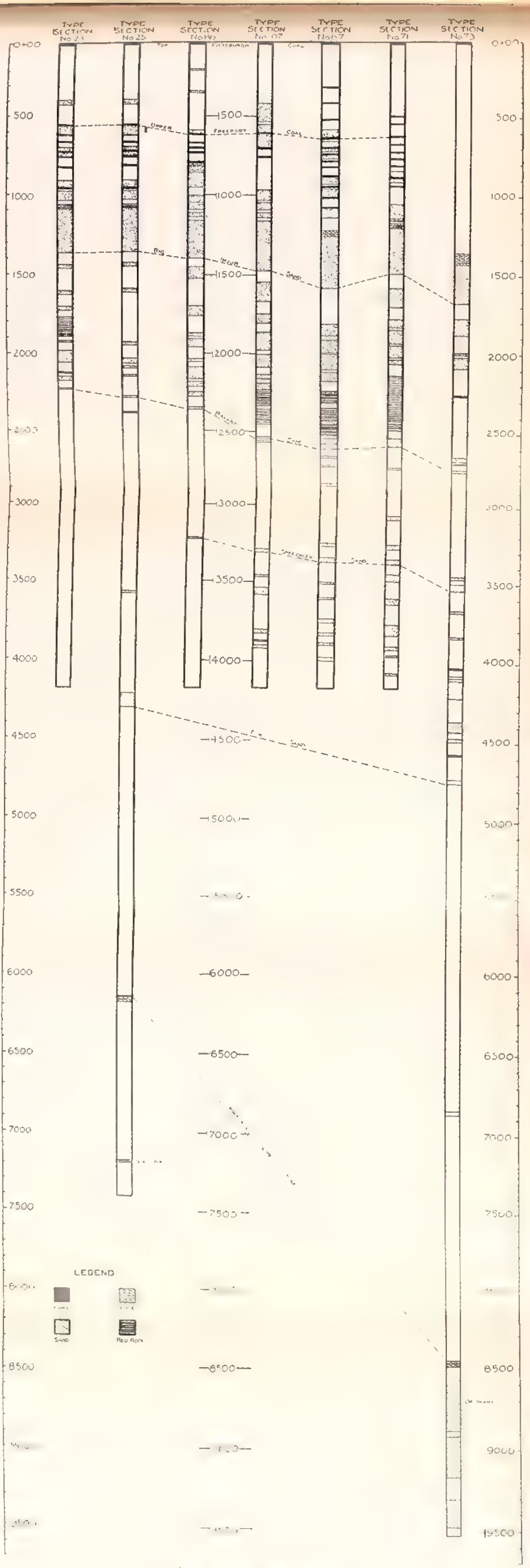


Fig 2. Section "AA" in Detail.



TYPE SECTION No 23
TYPE SECTION No 25
TYPE SECTION No 45
TYPE SECTION No 07
TYPE SECTION No 67
TYPE SECTION No 71
TYPE SECTION No 73
UPPER FREEPORT COAL
BIG INJUN SAND
SPECHLEY SAND
LEGEND
SAND
RED ROCK

STRATIGRAPHY OF SOUTHWESTERN PENNSYLVANIA*

By J. French Robinson†

Introduction. Since Colonel Drake drilled his first well in 1859, approximately 100,000 wells have been drilled in Southwestern Pennsylvania. These wells have been drilled to varied depths, ranging from a few feet to nearly 8000 feet, with an expenditure exceeding $500,000,000.

Notwithstanding the investment made, very little detailed study has been given to the correlation of the various horizons penetrated. Hundreds of wells have been abandoned before they reached the horizon to which they were supposed to have been drilled, while many other wells have been drilled hundreds of feet deeper than necessary to reach the last known producing sand.

The following information is given with the thought of eliminating the above conditions. The information which follows was obtained from a study of more than 50,000 well logs, many diamond-drill cores, and various outcrops of coal, limestone, and sandstone horizons.

Description of Work Map. Fig. 1 shows the portion of Southwestern Pennsylvania considered in this study. The area studied has been divided into units, for the purpose of making type sections. These units, which are numbered on the map, are in most cases townships, but occasionally two or more townships are combined. The numbers ranging from 1 to 184 provide a ready reference to a type section in any county.

The direction of sections "AA" and "BB" is indicated on the map.

Description of Type Section. The logs of individual wells within a unit area were plotted on strips of paper, showing all coals, limes, and sands penetrated, together with water and all oil and gas pays.

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From a detailed study of these sections, an average or type section for the unit area was made by averaging intervals and thicknesses of formations. An important point in a study of this kind was to determine a key formation on which to base the results. Care was taken to select a formation that could be identified and was continuous over a great area. In this study, the Pittsburgh coal horizon was used as the key formation in Greene, Washington, Beaver, Allegheny, Fayette, and Westmoreland counties, while the Upper Freeport coal horizon was used as the key formation in Butler, Armstrong, Indiana, Clarion, and Jefferson counties.

Use of Type Sections. These type sections should prove valuable to any operator, for the following purposes:

1. To identify all coal seams which should be protected.
2. To drill the necessary depth of the proper sized holes.
3. To provide the required amount of casing before drilling.
4. To make sure he is not passing up a chance for production, by not drilling deep enough.
5. To make sure he is not drilling deeper than necessary to reach the last known sand.

The value of these type sections depends upon the proper identification and location of the key formation. Sometimes this is difficult, making it necessary to do field work, such as running levels and studying outcrops.

Having decided to drill a well, the first step is to determine the elevation of the proposed location, either by running levels or from a map. Approximate elevations, both surface and structure at any point, can be obtained from the United States Geological Survey folios, which cover the larger part of the producing area of Southwestern Pennsylvania.

In some cases, neither the well elevation nor the structure information are available. Even under these conditions it is possible to use the type section to advantage, because in almost any part of Southwestern Pennsylvania the farmer or some local person has some fairly reliable information relative to local formations. They will be able to tell you the depth of the Pittsburgh coal at some point, or that a

certain coal has been mined, or lime quarried nearby, and from this information you can get an approximate tie to the type section.

With this tie established, the interval to the key formation can be added to or subtracted from the type section, thereby giving a fairly good record of the proposed well before it is drilled. For example; the elevation of a proposed well in Springhill Township, Greene County, is 1350 feet above sea-level, and from the United States Geological Survey folio the elevation of the Pittsburgh coal horizon is 350 feet above sea-level. The Pittsburgh coal will thus be found at a depth of 1000 feet. If we now add 1000 feet to our type section for Springhill Township, Greene County, we will have very closely a detail record of the well before it is drilled.

Description of Sections. Section "AA," in Fig. 2, extends in a northeasterly direction from Greene County to Jefferson County, and nearly parallels the old shore line. There is slight thinning to the north. Nearly all the horizons are parallel with very little evidence of non-conformity. However, if a detail study of the type sections along Section "AA" be made, some local thickening and thinning will be noticed.

Section "BB," in Fig. 3, extends from Hanover Township, Washington County, to Ligonier Township, Westmoreland County. A marked thickness can be noticed in this direction. The interval from the Pittsburgh coal to the corniferous lime in Robinson Township, Washington County (type section No. 25), is 6135 feet, while in Ligonier Township, Westmoreland County (type section No. 73), the interval between the same horizons is 8435 feet. By a comparison of the type sections between these points, one can see the need for type sections and small unit areas.

Geology and Topography. Besides the thickening and thinning above mentioned, two other factors account for the depths from the surface to the various horizons; these factors are geology and topography.

The great Appalachian oil and gas field, of which Pennsylvania is a part, lies in a geosyncline or bowl-shaped structure, west of the Allegheny Front, and extends from New York state to Alabama. The strata are so folded as to resemble an oblong bowl, the major axis of which extends in a general northeast and southwest direction. The

center of the geosyncline is located near Wileyville, Wetzel County, W. Va., only a few miles from the Pennsylvania state line. This is the lowest point structurally in the Appalachian field. The Pittsburgh coal has an elevation of zero (based on sea-level) at this point. In Springhill Township, Greene County, Pa., the Pittsburgh coal has an elevation of 200 feet, while at Pittsburgh it has an elevation of 1300 feet. The various strata rise in all directions from the low point. They are, however, disturbed by other folding upon the major fold. On account of this folding, the Pittsburgh coal and all other strata resemble a wave. The difference in elevation between the high and low points of the wave may be several hundred feet.

All of our known producing horizons outcrop in Central Pennsylvania. The rise to the north is gradual. The Murrysville sand outcrops near Corry, Pa., and the Gordon sand outcrops near Salamanca, N. Y.

Topography shows the physical features of the earth's surface, which are usually represented by contour lines on maps. Most topographic maps are based on sea-level datum.

Just as topography outlines the hills and valleys on the surface, geologic structure outlines the hills and valleys beneath.

Producing Horizons. The following horizons produce either oil or gas, or both, in Southwestern Pennsylvania:

1. Pittsburgh coal.
2. Murphy sand.
3. Little Dunkard sand.
4. Big Dunkard sand.
5. Upper Freeport coal.
6. First gas sand.
7. First salt sand.
8. Second salt sand.
9. Third salt sand.
10. Maxton sand.
11. Big Injun sand.
12. Squaw sand.
13. Second gas sand.
14. Murrysville sand.

15. Gantz sand } Hundred-foot sand.
16. Fifty-foot sand }
17. Thirty-foot sand.
18. Snee sand.
19. Gordon stray sand.
20. Gordon sand.
21. Fourth sand.
22. Fifth sand.
23. First Bayard sand.
24. Second Bayard sand.
25. Third Bayard sand.
26. Elizabeth sand.
27. Warren sand.
28. Speechley stray sand.
29. Speechley sand.
30. Tiona sand.
31. First Balltown sand.
32. Second Balltown sand.
33. Sheffield sand.
34. First Bradford sand.
35. Second Bradford sand.
36. Third Bradford sand.
37. First Kane sand.
38. Second Kane sand.
39. Third Kane sand.
40. Oriskany sand.
41. Stormville sand.

Is it any wonder that the drilling on many wells is stopped too soon, when we have a total of 41 producing horizons, of which 39 occur in an interval of less than 4000 feet? The producing sands vary from a few feet in thickness to nearly 300 feet. The total thickness of sand over the 4000-foot interval covers about 35 per cent. of the total. Each sand varies in thickness in different localities. Some sands pinch out and wedge in, while stray sands appear and disappear.

In view of the above facts, and the writer's experience in correlating well logs, it seems impossible to name the sands of Southwestern Pennsylvania properly or consistently without using type sections.

Observations. The writer has observed that many well logs are incorrect from top to bottom. In others, only a portion is incorrect, while in some only one or more sands are misnamed. In most cases the naming of the sands has been left to the driller. Due to his training and the information he has at hand, he has performed his duty remarkably well, but too much has been expected of him. It is now time to give him some assistance.

Results Desired. In presenting this information, it is the hope and desire of the writer that the following results be obtained:

1. All workable coal beds will be protected.
2. Better well records will be kept.
3. No wells will be abandoned before the desired horizon is reached.
4. Less drilling will be done below known producing horizons.

TABLE I—GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS BELOW THE PITTSBURGH COAL—ALLEGHENY COUNTY

(Each township column gives Top and Bottom depths, in feet, below the Pittsburgh coal.)

[illegible]	[illegible] Township (79)	North Fayette Township (80)	Moon Township (81)	Sewickley Heights and Vicinity (82)	[illegible] (83)	Marshall Township (84)	South Fayette Township (85)	Collier Township (86)	Robinson Township (87)	Pittsburgh and Vicinity (88)	Ross Township (89)	McCandless Township (90)	Pine Township (91)	Upper St. Clair and Mt Pleasant Townships (92)	Scott Township (93)	Bethel Township (94)	Baldwin Township (95)	Shaler Township (96)	Hampton Township (97)	Richland Township (98)	Snowden Township (99)	Forward and Elizabeth Townships (100)	Jefferson Mifflin and Lincoln Townships (101)	[illegible] Township (102)	Penn Township (103)	O'Hara Township (104)	Harmar and Indiana Townships (105)	West Deer Township (106)	Versailles Township (107)	North Versailles Township (108)	Patton Township (109)	Plum Township (110)	East Deer and [illegible] Townships (111)	Fawn Township (112)	Harrison Township (113)
Pittsburgh coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morgantown sand		215 300					150 200	175 185										[illegible]	360	360	330				370			360							
[illegible]										350	350	[illegible]15	380			310													420 [illegible]						
[illegible]																	365 420				480				500	450	410								
[illegible]				540							540		520					540	530									510		550		[illegible]			
[illegible] sand							515 590	570 600								580 610	540 590				545 600			560 [illegible]	555 625				550 600		45 615	615 670			
Upper Freeport coal	565	550	570	600	[illegible]		600	600	590	585	580	[illegible]	590	605	570	610	600	[illegible]	590	585	600	605	610	610	630	660	600	585	600	615	25	670	665	[illegible]	[illegible]
[illegible] Freeport sand		600	610	650			650	660		650	645	[illegible]	640			680		640	640			650			690	660	650				70	725	710	[illegible]	[illegible]
[illegible] Freeport [illegible] sand	650	680		710			680	680	685		695	680	700	700	700	720		700	680	690	730	685	740	710	710	710	690	680	700	700	20	780		[illegible]	[illegible]
[illegible] sand															770 805		740 760																		
Middle Kittanning coal		710	740	765			720	720			750	735				760		[illegible]	750	750	770		810	795	800		750	750	750	790	785	825	825	800	[illegible]
Lower Kittanning coal	[illegible]	790	800		[illegible]	800	780	780	805	790	835	[illegible]	805	795		805		[illegible]	825	830	810	785	880	[illegible]	840	800	815	815	810	840	840	870		870	[illegible]
[illegible]port limestone				850	840			790 800			880	[illegible] 835							875 895	870 885		805 810			870 880		840 860	870 890			[illegible] 870	875 910		[illegible] 920	[illegible] 950
[illegible] sand	[illegible] 1020		860		[illegible] 905		850	800 840				810 910			885 925		840 870	[illegible]				850		880 [illegible]										[illegible]	[illegible]
[illegible]				890						880			850	885					900	890	905	810		920	890	900	910	890							
[illegible] sand		910 990	1050	980			1030	850 940	890					950	940 980	905 1000	930					1000	980 1065	960			980 1050	930 [illegible]	970 1035	960 1000	[illegible] 990	955 1025			
[illegible] coal		995				975					1040	1005	975					1000	1020	1000					1000	960		960							
[illegible] sand		1000 1080	1060 1110	1040	[illegible] 1085			990 1085		1010	1075	1010 1075	1000 1075	1010 1050	1000 1040	1010 1050	1050	1020 1095	1065	1010 1090	1025 1065							[illegible] 1040	1050 [illegible]			1040 1135			
Mercer coal						1065																				1040	1020	1040							
[illegible] sand								1100 1130	1140	1140	11[illegible]				1060 1080	1060 1100	1075 1120	1150 1200	1130 1190	1110 1170				1090 1110		1050 1150	1110 1190	1070 1140	1115 1150	1100 [illegible]	1100 1150	1135 1160	1130 1200	1110 1210	1115 1220
Little lime																1105 1125						1175 1185													
Big lime		1140 1150								1150 1200				1135 1190	1100 1120	1145 1180	1130 1170				1150 1200	1205 1250	1170 1210	1110 [illegible]	1140 1185					1185 1210		1160 1200			
Big Injun sand	1120 1310	1150 1580	1150 1570	1100	[illegible] 1380	1120 1350	1110 1110	1130 1390	1190 1410	1200 1540	1200 [illegible]	1110 1385	1110 1340	1190 1410	1120 1430	1180 1430	1170 1450	[illegible] 1430	1200 1415	1200 1570	1200 1130	1250 1525	1210 1510	1170 [illegible]	1185 1530	1160 1410	1200 1425	1150 [illegible]	1165 1475	1210 [illegible]	1185 1515	1290 1510	1240 1600	1220 [illegible]	1230 [illegible]
Squaw sand	1410 1485	1500 1540	1420 1450		[illegible] 1570	1400 1510	1460 1525	1445 1515	1490 1535		1430 1510	1400 1510	1370 1480		1460 1560	1480 1570		1450 1590	1500 1600		1470 1570	1560 1660	1560 1675	1580 [illegible]	1590 1695	1450 1580	1440 1580		1510 1665	1560 [illegible]	[illegible] 1700	1570 [illegible]	1540 1640	1535 [illegible]	
[illegible] sand	1640 1660	1750 1780	1705 1730	1630	[illegible]	1710		1690 1750	1700 1760			1685 1705	1800 1650	1710 1760	1710 1765	1780 1810	1720 1855				1760 1800		1700 1810	1770 [illegible]	1785 1825	1610 1710	1620 1680		1745 1800	1700 [illegible]	[illegible] 1810	1700 1800	1700 1810	1740 1910	[illegible]
Mu[illegible] sand	1730 1760			1785	[illegible]	1855 1730	1860	1700 1730	1860 1880	1850 1910	1710 1840	1730 1840	1700 1800		1885	1935 1900	1920 1975	1710 1870	1765 1865	1730 1830	1920 2000	1830 1900	1890 1980	1865 [illegible]	1885 1875	1770 1880	1770 1870	1740 1840	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gantz sand		1900	1905 1900	1950		1875	1880	1900	1870	1990	1900	1860	1850	1890	1940	2000	[illegible]	[illegible]	[illegible]	1860	2050	1915	1975 2000	1970	2010	1990	1895	1880	[illegible]	2010	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fifty-foot sand	1880 1920	1920 1930	[illegible]	1990	[illegible]	1980	1920 1980	1990		2000						2085 2100	2070	2010		2010	2100	1990	2075		2150	2100									
Thirty-foot sand	1965 1985	2010	2000 2025	2050	[illegible]	2050 2020	2050 2030	2020	2000 2045 2050	2070 2110	2160 2080	2020	2045 1990	2030 2040	2080 2050	2080 2145	2110 2165 2100	[illegible]	2020	2050 2010	2050 2145	2070 2165	2130 2140	2160 2110	[illegible]	2160 2060	2095 2030	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stray sand		2080	2080	2095									2070	2090			2135	2120	2150 2170	2100 2080	2120	2140	2160 2170	2210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gordon stray sand	2020	2080 2100	2130 2115	2135	[illegible]	2115 2120	2145 2080	2100 2075	2100	2170 2210	2130	[illegible] 2080	2110 2110	2120 2130	2170 2110	2150 2220	2160 2120	2180	2120	2150 2130	2170	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gordon sand	2075	2090 2100	2180 2100	2180	[illegible]	2160 2150	2160 2105	2150	2150	2160 2250	2160	2135	2135 2150	2170 2200	2220 2185	2220 2250	2215 2210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fourth sand	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2220	2170	2175	2200	[illegible]	[illegible]	2190	[illegible]	2200	2260	2300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fifth sand	[illegible]	2250	2290 2250	2265		2260	2240	2230 2260	2260	2380	2285	2210	[illegible] 2300		2320	2350	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Bayard sand										2110			2320			2155 2140	2155 2170				2130 2170	2110 2190	2500 2555	2540 2500		[illegible]	2150 2180	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Second Bayard sand								2330 2335		2490 2520									2380	2407			2555			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2600	
Third Bayard sand																																			
Elizabeth sand																																			
First Warren sand					2540 2560								2600 2610							2670 2720															
Second Warren sand													2720 2750						2750 2820								2770 2880								
Third Warren sand													2900 2910																						
Speechley stray sand			3170 3175		3115 3125								3040 3050		3170				3180 3120	3135 3030	3045	3255	3275 3300	3215 [illegible]	3200		3115	[illegible]	[illegible]	3410	3450 3410	[illegible]	[illegible]	3240 3160	3240 [illegible]
Speechley sand																											3250								
Tiona sand								3260 3270		3230 3250				3250 3270																					
First Balltown sand															3320																			3300	3415 3370
Second Balltown sand														3450 3490																					
Sheffield sand																															3640 3880			3730	3800 3770
First Bradford sand																								3770	3780										
Second Bradford sand																								3805	3880				3705		3950	[illegible]	3850	3930	3950 3870
Third Bradford sand																								3915	3930				3895	3915		4040	4030		3890

TABLE II

GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS BELOW UPPER FREEPORT COAL—ARMSTRONG COUNTY

Name of Formation	South Buffalo Township (128) Top	Bottom	North Buffalo Township (129) Top	Bottom	West Franklin Township (130) Top	Bottom	Sugar Creek Township (131) Top	Bottom	Bradys Bend Township (132) Top	Bottom
Upper Freeport coal	0		0		0		0		[illegible]	
Lower Freeport coal			50		50		65			
Upper Kittanning coal			100		100				[illegible]	
Middle Kittanning coal	210		170		180				[illegible]	
Lower Kittanning coal	250		220		265		230		[illegible]	
Vanport limestone	270	290	240	260	280	300	285	300		
Clarion coal	335				320				[illegible]	
Craigsville coal			360							
Brookville coal										
Homewood sand	340	390					380	440	[illegible]	400
Mercer coal			400							
[illegible] sand	430	505	420	480			450	510		
Little lime										
Pencil Cave										
Big lime			490	505						
Big Injun sand	515	700	505	830	490	940	520	800	[illegible]	700
Squaw sand			910	1010	950	1020	820	1000	[illegible]	930
Second gas sand	1120	1150	1090	1140	1050	1120	1080	1110	[illegible]	1080
Murrysville sand	1190	1240	1160	1225	1180	1240	1160	1260		
Hundred-foot sand	1275	1375	1250	1320	1270		1300	1380	[illegible]	1300
Thirty-foot sand	1395	1420	1340	1400		1380	1410	1445		
Stray sand	1460	1490	1410	1440	1410	1460	1460	1500	[illegible]	1450
Gordon stray sand	1505	1530	1475	1510	1490	1540	1520	1560	[illegible]	1530
Gordon sand	1600	1620	1550	1575	1500	1595	1580	1620	[illegible]	1625
Fourth sand	1665	1700	1615	1680	1615	1700	1660	[illegible]		
Fifth sand			1715	1740	1730	1750				
First Bayard sand			1780	1810	1800	1820				
Second Bayard sand					1900	1910				
Elizabeth sand					1950	1980				
First Warren sand					2070	2085				
Second Warren sand					2185	2220	2150	[illegible]		
Third Warren sand					2400	2420				
Speechley stray sand	2480	2495	2470	2510	2460	2500			[illegible]	2470
Speechley sand	2515	2560	2560	2590	2500	2600	2500	2540		
Tiona sand			2080	2700	2720	2750	2630	[illegible]		
First Balltown sand					2890	2000	2800	2830		
Second Balltown sand										
Sheffield sand										
First Bradford sand							3000	[illegible]		
Second Bradford sand										
Third Bradford sand							3140	[illegible]		
First Kane sand										
Second Kane sand										
Third Kane sand										
First Elk sand										
Second Elk sand										
Third Elk sand										

Name of Formation	Gilpin Township (133) Top	Bottom	Bethel Township (134) Top	Bottom	Manor Township (135) Top	Bottom	Reyburn Township (136) Top	Bottom	East Franklin Township (137) Top	Bottom
Upper Freeport coal	0		0		0		0		0	
Lower Freeport coal	50		60		50		55		65	
Upper Kittanning coal	90		100		90		105		105	
Middle Kittanning coal	165				170		160		160	
Lower Kittanning coal	225		220		225		220		235	
Vanport limestone	260	270	250	270	250	270	260	270	270	290
Clarion coal	290		290		285					
Craigsville coal	370		355		345		325			
Brookville coal					390		375			
Homewood sand	310	470					380		370	410
Mercer coal			400							
[illegible] sand	485	530	405	435					430	
Little lime										
Pencil Cave										
Big lime			445	470	450	480				
Big Injun sand	540	970	470	900	480	850		835		840
Squaw sand	1015	1065	950	1030	950	1000	910	990	920	1010
Second gas sand	1120	1180	1070	1120						
Murrysville sand	1200	1280	1150	1230	1150	1230	1120	1210	1150	1230
Hundred-foot sand	1300	1390	1240	[illegible]	[illegible]	1320	1220	1310	1250	1340
Thirty-foot sand	1410	1440	1340	1390	[illegible]		1320	1390	1350	1410
Stray sand			1410	1440		1430			1440	1470
Gordon stray sand	1585	1595			1500	1530			1530	1560
Gordon sand	1600	1690	1620	1640	1550	1610			1590	1610
Fourth sand			1680	1710	1670	1700	1640	1700	1650	1680
Fifth sand	1790	1810	1760	1820	1740	1820	1730	1790		
First Bayard sand	1850	1870					1860	1880		
Second Bayard sand					1915	1945				
Elizabeth sand			1930	1950						
First Warren sand			2010	2030						
Second Warren sand	2250	2270			2140	2210				
Third Warren sand										
Speechley stray sand	2500	2540	2110	2470	2490	2510	2475	2490		
Speechley sand	2610	2670	2550	2580	2540	2550	2525	2580	2530	2570
Tiona sand	2740	2760	2670	2700	2690	2720	2690	2720		
First Balltown sand	2800	2855	2790	2830	2790	2830			2805	2835
Second Balltown sand	2930	2950			2910	2020				
Sheffield sand	3100	3120							2960	3025
First Bradford sand	3190	3230	3110	3160	3100	3130			3150	3190
Second Bradford sand	[illegible]	[illegible]			[illegible]	3250			3210	3270
Third Bradford sand	3350	3380	3230	3270	3285	3300			3305	3330
First Kane sand					3385	3430				
Second Kane sand										
Third Kane sand					3500	3540				
First Elk sand										
Second Elk sand										
Third Elk sand										

Name of Formation	Washington Township (138) Top	Bottom	Parks Township (139) Top	Bottom	Burrell Township (140) Top	Bottom	Kittanning Township (141) Top	Bottom	Valley Township (142) Top	Bottom
Upper Freeport coal	0		0		0		0		0	
Lower Freeport coal	65		65		50		50		60	
Upper Kittanning coal			120		100		90		110	
Middle Kittanning coal	165		175		150		150			
Lower Kittanning coal	240		[illegible]		200		200		230	
Vanport limestone	255	270	260	275	240	260	230	250	250	260
Clarion coal	290		280		305				300	
Craigsville coal			370						350	
Brookville coal										
Homewood sand	340	440	305	440	400		400		370	410
Mercer coal			445							
[illegible] sand	460	540	450	510						
Little lime										
Pencil Cave										
Big lime										
Big Injun sand	550	880	520	900		800		900	500	830
Squaw sand	900	1000	950	1070	820	930	950	1040	880	930
Second gas sand	1030	1070			1050	1080	1050	1130	1010	1110
Murrysville sand	1110	1190	1180	1265	1140	1190	1110	1230	1150	1250
Hundred-foot sand	1220	1340	1280	1380	1210	1320	1250	1390	1270	1350
Thirty-foot sand	1350	1390	1400	1440	1350	1420	1410	1450	1380	1430
Stray sand	1410	1450							1450	1500
Gordon stray sand	1490	1530	1555	1570						
Gordon sand	1560	1600	1635	1650	1640	1680	1600	1625	1610	1630
Fourth sand			1760	1780	1710	1730	1690	1710	1710	1730
Fifth sand	1700	1730	1820	1850	1800	1835	1750	1810	1785	1830
First Bayard sand	1700	1810	1895	1910			1840	1850	1880	1900
Second Bayard sand							1880	1895		
Elizabeth sand							1970	2000		
First Warren sand	2100	2120								
Second Warren sand							2250	2326		
Third Warren sand					2150	2460	2130	2180		
Speechley stray sand	2360	2380			2530	2500	2500	2590	2500	2550
Speechley sand	2440	2460	2600	2650	2610	2650	2610	2650	2570	2650
Tiona sand	2570	2600	2730	2770	2730	2760	2710	2750	2700	2780
First Balltown sand	2740	2760	2790	2830	2850	2870	2760		2850	2900
Second Balltown sand			2900	2940	2930	2955				
Sheffield sand	2950	3000	2990	3050	3035	3060	2950	2980	2910	2950
First Bradford sand	3040	3070	3140	3160	3120	3150	3050	3100	3000	3070
Second Bradford sand	3120	3115	3200	3220	3190	3210	3120	3190	3100	3180
Third Bradford sand	3190	3240	3265	3290	3285	3320	3210	3280	3240	3260
First Kane sand	3280	3300	3365	3385	3380	3400	3335	3365	3300	3360
Second Kane sand	3350	3370							3400	3440
Third Kane sand							3460	3480		
First Elk sand										
Second Elk sand										
Third Elk sand										

Name of Formation	Boggs Township (143) Top	Bottom	Pine Township (144) Top	Bottom	Madison Township (145) Top	Bottom	Kiskiminetas Township (146) Top	Bottom	South Bend Township (147) Top	Bottom
Upper Freeport coal	0		0		0		[illegible]		0	
Lower Freeport coal	50				45		50		55	
Upper Kittanning coal	90				90		110		115	
Middle Kittanning coal	140				135				155	
Lower Kittanning coal	200				200		200		205	
Vanport limestone	230	240	230	240	215	230	[illegible]	235	230	245
Clarion coal	300		290		290				280	
Craigsville coal					370		[illegible]			
Brookville coal										
Homewood sand							[illegible]	420	315	400
Mercer coal			450						415	
[illegible] sand	410						[illegible]		450	
Little lime										
Pencil Cave										
Big lime										
Big Injun sand		730	510	970	630	650		850		880
Squaw sand					840	860	880	1020	900	1000
Second gas sand			1000	1060	1020		1070	1090	1020	1110
Murrysville sand	1080	1200	1080	1170		1100	1150	1260	1130	1225
Hundred-foot sand	1230	1330	1200	1310	1150	1270	1270	1360	1235	[illegible]
Thirty-foot sand	1350	1400	1335	1355	1310	1330	1370	1400	1350	[illegible]
Stray sand			1375	1400	1370	1400	1410	1450	1435	[illegible]
Gordon stray sand	1540	1570			1410	1450			1510	1530
Gordon sand			1510	1540	1530	1570	1560	1590	1585	1610
Fourth sand	1630	1660	1600	1630			[illegible]	1700	1680	1700
Fifth sand	1700	1750	1700	1730			1750	1800	1740	1760
First Bayard sand	1790	1810	1810	1820					1820	1850
Second Bayard sand							1850	1880	1880	1900
Elizabeth sand									1940	1960
First Warren sand			2150	2170			2040	2100	2030	2120
Second Warren sand							2210	2260	2290	2350
Third Warren sand							2390	2425	2430	2460
Speechley stray sand	2430	2470			2390	2430	2530	2550	2500	2520
Speechley sand	2490	2530	2490	2530	2480	2500	2570	2620	2565	2620
Tiona sand	2610	2640	2630	2660	2580	2600	2720	2780	2700	2760
First Balltown sand	2680	2710	2730	2750	2710	2760	2860	2870	2850	2870
Second Balltown sand	2760	2800	2810	2830	2800	2820	2920	2950	2910	2950
Sheffield sand	2830	2030	2870	2920	2890	2940	2990	3010	2970	3030
First Bradford sand	3030	3060			2980	3000	3050	3080	3050	3130
Second Bradford sand	3090	3130			3100	3130	3150	3200	3150	3190
Third Bradford sand							3210	3260	3270	3300
First Kane sand	3270	3290	3280	3320						
Second Kane sand					3360	3400				
Third Kane sand							3485	3510		
First Elk sand							3600	3615		
Second Elk sand							3660	3670		
Third Elk sand							3740	3750		

Name of Formation	Plum Creek Township (148) Top	Bottom	Cowanshannock Township (149) Top	Bottom	Wayne Township (150) Top	Bottom	Mahoning Township (151) Top	Bottom	Red Bank Township (152) Top	Bottom
Upper Freeport coal	0		0		0		0		[illegible]	
Lower Freeport coal	60		50							
Upper Kittanning coal	110		95		85					
Middle Kittanning coal	170				125					
Lower Kittanning coal	225		210		200				260	
Vanport limestone	240	250	240	260	260	270	240	250	250	260
Clarion coal			280		280					
Craigsville coal					350		340			
Brookville coal										
Homewood sand	300	350	310	350						
Mercer coal					400					
[illegible] sand	390	450	410		410		440		450	
Little lime										
Pencil Cave										
Big lime										
Big Injun sand	470	850		810		740		780		800
Squaw sand	950	1000	900	1010	820	890	840	940	[illegible]	910
Second gas sand	1080	1110	1060	1110	[illegible]	1010	970	[illegible]	[illegible]	995
Murrysville sand	1130	1230	1140	1210	1100	[illegible]	[illegible]	[illegible]	[illegible]	1150
Hundred-foot sand	1240	1360	1260	1340	1200	1340	[illegible]	[illegible]	[illegible]	1275
Thirty-foot sand	1375	1400	1350	[illegible]	1350	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stray sand			1410	[illegible]	1420	[illegible]	1380	[illegible]	[illegible]	1395
Gordon stray sand			1470	1510	1475	1480			1455	1475
Gordon sand			1540	1580	1560	[illegible]	1550	[illegible]		
Fourth sand			1615	1635	1680	1690			[illegible]	1715
Fifth sand	1760	1790	1725	1760	1700	1810	1720	1750	[illegible]	1775
First Bayard sand					1830	1860			1825	1835
Second Bayard sand										
Elizabeth sand					1960	[illegible]	1890	1910		
First Warren sand	2160	2180			2040	2055	2170	2190	2300	2110
Second Warren sand					2240	2300				
Third Warren sand			2340	2400	2330	2370				
Speechley stray sand	2485	2520	2480	2510	2470	2510			2470	2515
Speechley sand	2575	2640	2560	2620	2550	2590	2470	2550	2530	2590
Tiona sand	2745	2780	2680	2700	2675	2765	2640	2680	2630	2680
First Balltown sand	2830	2865	2760	2800	2800	2840	2720	2770	2790	2830
Second Balltown sand	2915	2940	2830	2850	2875	2900	2830	2845	2860	2875
Sheffield sand	3000	3010	2910	3000	2945	2990	2880	2960	2910	2930
First Bradford sand	3040	3070	3020	3050	3040	3065	3020	3040		
Second Bradford sand	3110	3210	[illegible]	3110	[illegible]	3145			[illegible]	3120
Third Bradford sand	3250	3300	3170	[illegible]	3200	[illegible]				
First Kane sand	3325	3350			3325	3350			3500	3410
Second Kane sand					3390	3410				
Third Kane sand					3470	3490	3420	3410		
First Elk sand										
Second Elk sand										
Third Elk sand							3870	3790		

[illegible]

TABLE III

GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS BELOW THE PITTSBURGH COAL, BEAVER COUNTY

System	Series	Formation	Name of Formation	Hanover Township (74) Top	Bottom	Independence Township (75) Top	Bottom	Harmony and Hopewell Townships (76) Top	Bottom	Economy Township (77) Top	Bottom	Franklin, Marion and New Sewickley Townships (78) Top	Bottom
Carboniferous	Pennsylvanian	Monongahela	Pittsburgh coal.........	0		0		0		0		0	
		Allegheny	Upper Freeport coal.	550									
			Lower Kittanning coal........	780						800		790	
		Pottsville, Beaver River	Clarion coal..................	810								850	
			Brookville coal..................							975		940	
			Salt sand........................	900	935	880	1040	900	980				
			Maxton sand...............					1015	1035				
	Mississippian	Mauch Chunk, Burgoon	Big lime	1055	1085								
			Big Injun sand.............	1085	1380	1100	1140	1085	1260	1115	1350	1140	1380
		Pocono, Cuyahoga	Squaw sand.................			1335	1350	1340	1355	1400	1510	1460	1510
		Berea	Second gas sand..............	1560	1650	1510	1630	1525	1640			1680	1710
			Murrysville sand			1680	1695	1680	1700	1730	1865	1745	1850
Devonian	Upper	Catskill	Gantz sand................			1775	1795	1780	1800	1870		1890	
			Fifty-foot sand.......	1830	1850	1820	1840	1840	1855		1970		1980
			Thirty-foot sand............							2020	2050	2020	2050
			Snee sand................					2090	2095			2090	2100
			Gordon stray sand	1960	1970					2115	2155	2160	2175
			Godron sand	2025	2030							2200	2210
			Fourth sand........	2060	2075								
			Fifth sand..	2080	2110							2310	2330
	Middle	Chemung	Bayard sand............	2210	2220								
			Warren sand...........	2630	2710								
			Speechley sand.......	2920	2950								

TABLE IV

GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS BELOW THE UPPER FREEPORT COAL—BUTLER COUNTY

Series	Name of Formation	Cranberry Township (114) Top	Bottom	Jackson Township (115) Top	Bottom	Lancaster Township (116) Top	Bottom	Adams and Forward Townships (117) Top	Bottom	Connoquenessing and Butler Townships (118) Top	Bottom	Franklin and Center Townships (119) Top	Bottom	Clay Township (120) Top	Bottom	Middlesex and Penn Townships (121) Top	Bottom	Clinton Township (122) Top	Bottom	Jefferson Township (123) Top	Bottom	Summit and Oakland Townships (124) Top	Bottom	Buffalo Township (125) Top	Bottom	Winfield Township (126) Top	Bottom	Clearfield and Donegal Townships (127) Top	Bottom
	Upper Freeport coal.....	0		0		0		0		0		0		0		0		0		0		0		0		0		0	
	Lower Freeport coal.....							60		60								65						55		55		65	
	Upper Kittanning coal...									110														120		90			
	Middle Kittanning coal..			100						150		150		150				200						200		150		160	
	Lower Kittanning coal..					200		200				180		190		240		240						240		240			
	Vanport limestone......																	295	305	280	290	300	310	285	300	280	300	250	260
Beaver River	Clarion coal..			280						300				300				325						320		320			
	Craigsville coal..			330		330																							
	Brookville coal	375								365						350												380	
	Salt sand.......				430	480			450	440	520	450	490	500	530			450	520					350	400	345	400	400	460
	Mercer coal.....			470																									
	Maxton sand..	465		480	580	545	635	490	500			540	600	600	630	520	620	530				510	570	490	570	470	550	490	
Mauch Chunk	Little lime																												
	Pencil Cave																												
Burgoon	Big Injun sand		760	595	740	655	910	570	780	640	760	635	750	680	800	650	785		800					580	870	570	870		850
Cuyahoga	Squaw sand	795	815	790	890	975	1005	820	950	835	955	810	910	865	975	815	930	880	960							920	1000	920	985
Berea	Second gas sand...			1065	1100	1070	1095	1040	1100	1065	1100	1085	1120	1080	1120	1080	1100			1050	1080			1120	1180	1040	1140		
	Murrysville sand..	1135	1240	1125	1225	1125	1235	1130	1240	1125	1225	1140	1200	1140	1240	1130	1230	1160	1230	1110	1210	1140	1220	1190	1280	1180	1260	1190	1240
Upper	Hundred-foot sand	1275	1300	1260	1355	1300	1355	1280	1400	1315	1405	1305	1350	1300	1430	1300	1420	1300	1400	1290	1400	1270	1380	1300	1430	1280	1400	1320	1385
	Thirty-foot sand	1430	1450	1395	1445	1390	1410	1430	1470							1445	1475	1450	1495			1410	1430	1440	1470	1430	1470	1405	1450
Catskill	Snee sand	1490	1500	1405	1475	1455	1500	1490	1510	1500	1520	1500	1550	1500	1540	1500	1530	1520	1545	1480	1500	1450	1500	1490	1520	1490	1505	1470	1500
	Gordon stray sand	1545	1560	1505	1530	1520	1530	1540	1555	1570	1580			1555	1575	1550	1585	1555	1585	1520	1570	1530	1550	1570	1610	1530	1560	1510	1530
	Gordon sand	1580	1590	1555	1565	1560	1570	1580	1600	1615	1625	1630	1640	1600	1640	1615	1635	1625	1645	1615	1635			1630	1655	1580	1610	1585	1610
	Fourth sand..	1615	1635					1620	1650	1660	1680	1680	1690	1700	1720			1680	1700					1670	1710	1640	1680	1635	1680
	Fifth sand....	1735	1750					1720	1740					1760	1775			1750	1800	1715	1730			1770	1790	1730	1750	1700	1730
Middle, Chemung	First Bayard sand......							1790	1810					1810	1825									1870	1890			1800	1820
	First Warren sand.	2070	2090									2010	2030																
	Second Warren sand													2100	2125			2170	2240									2240	2250
	Third Warren sand																											2350	2400
	Speechley stray sand.	2310	2350					2340	2350					2300	2330			2380	2410					2460	2490	2490	2520	2490	2510
	Speechley sand	2470	2495					2480	2490	2530	2580	2530	2540	2520	2590			2505	2555					2550	2620	2580	2610	2580	2620
	Tiona sand.........							2565	2590									2625	2650					2700	2750	2720	2750		
	First Balltown sand													2720	2735			2715	2755					2900	2915	2915	2940		
	Second Balltown sand																	2830	2860										
	Sheffield sand																							2970	2980				
	First Bradford sand..																							3030	3050	3040	3080		
	Second Bradford sand																												
	Third Bradford sand																							3230	3240				
Lower, Portage	First Kane sand.																									3430	3450		
	Second Kane sand																									3510	3525		

TABLE V

GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS BELOW THE UPPER FREEPORT COAL—CLARION COUNTY

System	Series	Formation	Name of Formation	Madison Township (176) Top	Bottom	Toby Township (177) Top	Bottom	Licking Township (178) Top	Bottom	Piney Township (179) Top	Bottom	Porter Township (180) Top	Bottom	Monroe Township (181) Top	Bottom	Red Bank Township (182) Top	Bottom	Limestone Township (183) Top	Bottom	Clarion Township (184) Top	Bottom
Carboniferous	Pennsylvanian	Allegheny	Upper Freeport coal	0		0		0		0		0		0		0		0		0	
			Lower Freeport coal	65								[illegible]		50		40		50			
			Upper Kittanning coal	120								[illegible]		100		90		100			
			Middle Kittanning coal	170										170		130		150			
			Lower Kittanning coal	220								[illegible]		215		200		200		200	
			Vanport limestone	265	280	230	255	250	255			[illegible]	260	250	260	225	235	240	250	230	240
		Pottsville / Beaver River	Clarion coal	305						290		[illegible]		285		250		270		260	
			Craigsville coal	330						330		[illegible]		330		340		330			
			Brookville coal													380		350		350	
			Salt sand											350	400			360	430	355	400
			Mercer coal					440		420		[illegible]		440				410		410	
	Mississippian	Mauch Chunk	Little Lime																		
			Pencil Cave																		
		Burgoon	Big Injun sand	430	770	445	700	500	800	475	750	[illegible]	700	445	760	425	725	450	780	430	680
		Cuyahoga	Squaw sand	870	950	760	865			800	900	[illegible]	900	830	950	750	875	850	890	710	860
		Berea	Second gas sand									[illegible]	950	1000	1030	925	965	980	1000	910	970
			Murrysville sand	1100	1150	1040	1115	1075	1090	1075	1135	[illegible]	1135	1040	1110	1025	1125	1040	1120	990	1050
Devonian	Upper	Catskill	Hundred-foot sand	1225	1295	1180	1260	1100	1200	1195	1225	[illegible]	1260	1150	1235	1140	1240	1135	1255	1140	1240
			Thirty-foot sand			1280	1300	1230	1245	1265	1315			1250	1310	1255	1290	1290	1310	1290	1310
			Stray sand	1350	1380	1330	1355	1325	1340	1325	1385			1340	1380	1320	1335	1340	1360	1345	1390
			Gordon stray sand	1460	1510			1380	1420	1400	1410	[illegible]	1415	1460	1500	1400	1440	1440	1470	1490	1510
			Gordon sand	1550	1570	1510	1560	1500	1530	1485	1500	[illegible]	1550	1530	1550	1530	1550	1550	1570	1540	1550
			Fourth sand	1600	1620					1550	1575	[illegible]	1610	1600	1620	1600	1625	1620	1635		
			Fifth sand	1630	1650	1620	1635			1620	1650	1620	1640	1660	1690	1660	1680	1665	1690	1675	1710
	Middle	Chemung	First Bayard sand															1720	1760	1730	1760
			Second Bayard sand	1760	1775									1770	1785	1780	1800				
			Elizabeth sand					1930	1955	1870	1970			1860	1950	1870	1910	1900	1915	1880	1900
			First Warren sand	2040	2060									2050	2080	2115	2125	2100	2135	2060	2095
			Second Warren sand					2130	2155	2120	2140					2180	2200				
			Third Warren sand					2270	2205	2275	2300			2270	2290	2260	2275	2280	2300	2290	2315
			Speechley stray sand	2380	2400									2380	2400	2350	2360				
			Speechley sand	2460	2490	2400	2425	2420	2435	2440	2460	2440	2480	2420	2440	2420	2460	2410	2435	2415	2450
			Tiona sand	2590	2625					2525	2550	2560	2580	2520	2590	2530	2560	2520	2545	2545	2565
			First Balltown sand					2610	2635	2630	2650			2660	2680	2650	2660	2640	2660		
			Second Balltown sand	2720	2745	2740	2760	2750	2765	2730	2750	2750	2770	2705	2780	2700	2765	2730	2755	2720	2740
			Sheffield sand	2765	2825	2790	2840			2780	2810	2830	2845	2800	2830	2800	2830	2800	2830	2860	2890
			First Bradford sand	2910	2940			2900	2910	2900	2950			2900	2920	2910	2950	2950	2970	2950	2980
			Second Bradford sand									3000	3015	3025	3050	3000	3020	3000	3020		
			Third Bradford sand	3090	3215					3080	3100			3080	3095			3075	3090	3075	3090
	Lower	Portage	First Kane sand											3250	3260	3170	3190	3200	3220	3175	3195
			Second Kane sand													3210	3235				
			Third Kane sand	3285	3300					3320	3360			3360	3370	3340	3370	3330	3350	3335	3355
			First Elk sand	3490	3515									3450	3445						
			Second Elk sand																		
			Third Elk sand																		

TABLE VI

GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS ABOVE AND BELOW THE PITTSBURGH COAL—FAYETTE COUNTY

System / Series	Name of Formation	Springhill Township (48) Top	Bottom	Nicholson Township (49) Top	Bottom	German Township (50) Top	Bottom	Luzerne Township (51) Top	Bottom	Me[illegible] Township (52) Top	Bottom	Redstone Township (53) Top	Bottom	Jefferson Township (54) Top	Bottom	Washington Township (55) Top	Bottom	Perry Township (56) Top	Bottom
Carboniferous — Pennsylvanian	Upper Waynesburg coal							355						360					
	Mapletown coal					100		105											
	Redstone coal	50																	
	Pittsburgh coal	0		0		0		0		0		0		0		0		0	
	Bakerstown coal	380																	
	Little Dunkard sand	415	490					470	530										
	Brush Creek coal																		
	Mahoning coal	500	560					570		56		570		550				530	
	Big Dunkard sand	550	620	565	620	460	580	580	630			590	640	510	590				
	Upper Freeport coal			625		600		630		605		615		620		650		605	
	Lower Freeport coal																	650	
	Upper Kittanning coal															860			
	First gas sand	765	820	780	840	740	760			760	83	770	835					760	800
	Middle Kittanning coal	710		770		730		770		750		760		770					
	Lower Kittanning coal			850															
	First salt sand	830	900	850	960	780		850		87		880				830	890		
	Clarion coal																		
	Second salt sand			980	1010		960		1050					910	1030	920	1040	890	940
	Third salt sand			1030	1100	1020	1080	1070	1110		1090		1100			1060	1130		
	Mercer coal																	1060	
	Maxton sand																	1110	1190
Mississippian	Little lime	1225	1240	1170	1190					1150	1175			1170	1200	1200	1225		
	Big lime	1250	1280	1200	1240	1160	1230	1200	1250	1185	1250	1195	1260	1220	1260	1240	1280	1205	1250
	Big Injun sand	1280	1490	1240	1560	1230	1490	1250	1620	1250	1485	1260	1500	1260	1560	1280	1585	1250	1500
	Squaw sand							1600	1700							1610	1720	1515	1610
Berea	Second gas sand	1850 1950	1860	1800	1830	1790	1820	1800	1820					1800	1820			1800	1820
	Murrysville sand	-	1990	1870	1910	1830	1920	1850	1970	1850	1900	1870	1915	1890	1980	1920	1980	1850	1950
	Gantz sand	2000	2020	1920		1940	1980	1980		1915	1985	1940	1950	2000		2000	2040		
	Fifty-foot sand				2010				2050							2070	2130	2025	2045
	Thirty-foot sand							2090	2110	2060	2080	2075	2100		2140	2140	2170		
Devonian — Upper Catskill	Snee sand			2110	2120	2100	2130	2150	2170							2190	2220		
	Gordon stray sand					2145	2160	2210	2220							2230	2260		
	Gordon sand			2180	2190			2250	2280							2310	2340		
	Fourth sand					2255	2280	2300	2310										
	Fourth "A" sand			2300	2330			2330	2345										
	Fifth sand			2340	2415	2340	2390	2390	2400	2355	2390					2430	2470	2410	2425
	Fifth "A" sand							2440	2460			2440	247					2450	2465
Middle Chemung	First Bayard sand			2440	2450	2440	2485	2500	2520					2520	2540	2520	2540	2490	2505
	Second Bayard sand			2470	2480			2530	255					2560	2580	2570	2590		
	Third Bayard sand																		
	Elizabeth sand																		
	First Warren sand																		
	Second Warren sand																		
	Third Warren sand																		
	Speechley stray sand																	3160	3170
	Speechley sand																	3220	3240
	Sheffield sand																	3580	3600
	First Bradford sand																	3725	3735
Lower Portage	First Kane sand																	4045	4060
	Third Kane sand																	4230	4235
	First Elk sand																	4415	4430
	Third Elk sand																	4620	4655
	Sand																	5080	5100
	San																	5135	5145

TABLE VII

GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS ABOVE AND BELOW THE PITTSBURGH COAL—GREENE COUNTY

System	Series	Group	Name of Formation	Springhill Township (1) Top	Bottom	Aleppo Township (2) Top	Bottom	Richhill Township (3) Top	Bottom	Gilmore Township (4) Top	Bottom	Jackson Township (5) Top	Bottom	Center Township (6) Top	Bottom
Carboniferous	Pennsylvanian	Dunkard	Washington coal	500											
			Waynesburg "B" coal							470				475	
			Waynesburg "A" coal	440								450			
		Monongahela	Upper Waynesburg coal	385						390		400		370	
			Middle Waynesburg coal	340				340		340		350		340	
			Lower Waynesburg coal	320		300		295				300		310	
			Uniontown coal												
			Mapletown coal	90		100		100		90		90		90	
			Redstone coal									50			
			Pittsburgh coal	0		0		0		0		0		0	
		Conemaugh	Murphy sand	210	240	235	255	200	230	180	225	210	250	180	225
			Bakerstown coal					355							
			Little Dunkard sand	395	420	400	430	370	410	390	435	400	430	390	435
			Brush Creek coal												
			Mahoning coal												
			Big Dunkard sand	500	550	500	555	490	535	500	540	520	580	500	540
		Allegheny	Upper Freeport coal					535		540				555	
			Lower Freeport coal	600						610				620	
			Upper Kittanning coal	655				640						675	
			First gas sand	690	710	680	730	670	695	670	730	680	750	680	730
			Middle Kittanning coal			730		720						730	
			Lower Kittanning coal			810				810				800	
		Pottsville	First salt sand	780	850	815	860	770	840	815	900	815	915	810	870
			Clarion coal												
			Second salt sand	920	1020	920	1000	910	950	910	1000	950	1030	920	
			Third salt sand	1035	1070			960	1045	1050	1085				1055
			Maxton sand	1090	1130	1080	1115	1075	1090	1115	1160	1085	1115	1110	1135
	Mississippian	Mauch Chunk	Little lime	1130	1160	1130	1150	1115	1140	1180	1200	1115	1170	1140	1190
		Burgoon	Big lime	1175	1235	1160	1230	1150	1200	1210	1260	1180	1230	1200	1260
			Big Injun sand	1235	1500	1230	1480	1200	1480	1260	1525	1230	1480	1260	1540
	Pocono	Cuyahoga	Squaw sand	1520	1650	1570	1640			1590	1645	1550	1650	1615	1660
		Berea	Second gas sand	1730	1780	1740	1780	1765	1800	1750	1810	1710	1750	1740	1765
			Murrysville sand	1820	1860	1815	1860	1830	1860	1840	1900	1805	1850	1810	1800
Devonian	Upper		Gantz sand	1955	1985	1965	1985	1955	1970	1920	1950	1910	1960	1910	1960
			Fifty-foot sand	1995	2030	1990	2025	1980	2015	1970	[illegible]	1975	2020	2005	2050
			Thirty-foot sand	2050	2070	2050	2075	2025	2050	2040	[illegible]	2040	2070	2070	2100
		Catskill	Gordon stray sand	2085	2105	2080	2110	2075	2100	2095	[illegible]	2085	2115	2125	2140
			Gordon sand	2145	2170	2150	2180	2115	2145	2140	2180	2140	2200	2155	2200
			Fourth sand	2205	2230	2210	2230	2170	2190	2190	2220	2225	2240	2215	2235
			Fourth "A" sand					2210	2220	2240	2255			2245	2290
			Fifth sand	2275	2290	2245	2260	2250	2270	2295	2320	2280	2300	2310	2330
			Fifth "A" sand	2300	2310					2330	2360	2325	2340	2340	2370
	Middle	Chemung	First Bayard sand	2400	2408	2410	2415			2410	2420	2428	2435	2435	2440
			Second Bayard sand	2432	2440					2445	2452	2465	2475	2455	2465
			Third Bayard sand	2485	2490			2465	2470	2465	2472	2530	2540	2495	2510
			Elizabeth sand	2600	2610							2615	2625		
			Warren sand					2755	2785						

Name of Formation	Morris Township (7) Top	Bottom	Wayne Township (8) Top	Bottom	Franklin Township (9) Top	Bottom	Washington Township (10) Top	Bottom	Perry Township (11) Top	Bottom	Whiteley Township (12) Top	Bottom
Washington coal			500		520				525		500	
Waynesburg "B" coal	490						490		470		480	
Waynesburg "A" coal									440			
Upper Waynesburg coal	375		400		380		400		390		400	
Middle Waynesburg coal			350		340				340		340	
Lower Waynesburg coal	320		325		310		330				310	
Uniontown coal	220		185		180							
Mapletown coal	100		90		90		100		90		90	
Redstone coal					60				60			
Pittsburgh coal	0		0		0		0		0		0	
Murphy sand	140	200	190	245	200	230	170	230	160	250	200	240
Bakerstown coal	365		365		395							
Little Dunkard sand	370	415	375	420	400	470	450	500	380	400	400	450
Brush Creek coal	450								420		420	
Mahoning coal			495						500		475	
Big Dunkard sand	500	550	500	560	520	600	540	600	480	550	480	560
Upper Freeport coal	550		565		580		590		565		590	
Lower Freeport coal	600		625		640				610		640	
Upper Kittanning coal	645		705		720				685		680	
First gas sand	650	700	710	760	725	780	670	780	690	730	690	800
Middle Kittanning coal	700		760						735		750	
Lower Kittanning coal	760		800		800				780		820	
First salt sand	770	830	835	870	845	900	830	890	850	920	830	880
Clarion coal			880								880	
Second salt sand	860	920	930	1025	930	1065	920	1040	940	1030	925	1020
Third salt sand	925	1045	1050	1100					1070	1110	1050	1130
Maxton sand	1055	1080	1130	1160	1125	1140			1150	1170	1135	1155
Little lime	1100	1115	1190	1210	1170	1190	1145	1170	1185	1200	1165	1180
Big lime	1130	1175	1220	1265	1200	1250	1180	1230	1210	1255	1200	1245
Big Injun sand	1175	1455	1265	1525	1250	1535	1230	1530	1255	1525	1245	1520
Squaw sand	1510	1550	1565	1625	1620	1650	1590	1650	1600	1700	1590	1630
Second gas sand	1780	1800	1750	1780	1750	1780	1810	1855	1755	1800	1715	1760
Murrysville sand	1830	1870	1820	1850	1830	1860	1870	1930	1840	1880	1810	1870
Gantz sand	1910	1940	1885	1925	1960	2000	1985	2015	1930	1960	1900	1940
Fifty-foot sand	1945	2000	1960	2030	2005	2040	2020	2060	1970	2020	1950	2020
Thirty-foot sand	2050	2070	2050	2080	2050	2080	2080	2100	2035	2070	2040	2070
Gordon stray sand	2080	2100	2095	2120	2100	2150	2130	2150	2100	2140	2100	2110
Gordon sand	2115	2165	2145	2190	2165	2195	2190	2220	2175	2195	2140	2175
Fourth sand	2180	2215	2215	2240	2230	2255	2240	2290	2225	2245	2210	2235
Fourth "A" sand			2255	2270	2270	2290					2240	2250
Fifth sand	2245	2270	2290	2305	2340	2370	2340	2365	2290	2320	2290	2330
Fifth "A" sand			2325	2355							2350	2370
First Bayard sand			2435	2445			2410	2450	2390	2400	2400	2420
Second Bayard sand			2450	2460	2450	2460	2465	2480	2415	2425	2430	2440
Third Bayard sand	2485	2495	2475	2485	2470	2475			2435	2450	2475	2480
Elizabeth sand	2592	2600	2620	2640	2580	2590			2550	2560	2585	2590
Warren sand												

Name of Formation	Jefferson Township (13) Top	Bottom	Morgan Township (14) Top	Bottom	Cumberland Township (15) Top	Bottom	Greene Township (16) Top	Bottom	Dunkard Township (17) Top	Bottom	Monongahela Township (18) Top	Bottom
Washington coal							490		510			
Waynesburg "B" coal									420			
Waynesburg "A" coal					440							
Upper Waynesburg coal					375		380		360		350	
Middle Waynesburg coal	350						320					
Lower Waynesburg coal			320						270			
Uniontown coal											210	
Mapletown coal	100		110		120		120		100		110	
Redstone coal							40		40		50	
Pittsburgh coal	0		0		0		0		0		0	
Murphy sand	180	240	160	220			190	260	120	200	190	235
Bakerstown coal												
Little Dunkard sand	440	470	435	460	450	480	390	420	400	440	450	510
Brush Creek coal												
Mahoning coal	480											
Big Dunkard sand	510	590	530	560	550	590	530	585	550	610	530	590
Upper Freeport coal	600		590		595		590		610		600	
Lower Freeport coal	655						650		660		650	
Upper Kittanning coal	710		685				700		690		700	
First gas sand	720	810	690	730	700	810	710	780	700	750	710	820
Middle Kittanning coal	760		735				780		760		760	
Lower Kittanning coal	815						830				850	
First salt sand	830	900	830	850	830	915	840	900	820	920	860	920
Clarion coal												
Second salt sand	940	1000	930	1000	930	1030	920	990	940	1010	945	1035
Third salt sand	1015	1075			1075	1130	1010	1080	1050	1110	1040	1116
Maxton sand	1095	1110			1155	1175	1090	1120	1130	1150	1130	1170
Little lime	1130	1150	1125	1140	1180	1190	1150	1170	1155	1175	1190	1210
Big lime	1160	1220	1150	1210	1200	1250	1190	1250	1190	1240	1220	1280
Big Injun sand	1220	1480	1210	1505	1250	1440	1250	1530	1240	1510	1280	1515
Squaw sand	1570	1620	1590	1635	1580	1670	1600	1660	1600	1650	1600	1660
Second gas sand	1770	1810	1780	1835	1770	1830	1730	1760	1760	1790	1800	1820
Murrysville sand	1885	1915	1880	1950	1860	1930	1820	1850	1840	1870	1865	1890
Gantz sand	1930	1990	1960	2010	1960	1995	1900	1940	1920	1950	1910	1065
Fifty-foot sand	2000	2050	2020	2040	2005	2050	1950	2000	1965	2000	1980	2020
Thirty-foot sand	2065	2095	2085	2105	2070	2090	2015	2040	2030	2060	2030	2080
Gordon stray sand	2140	2185	2135	2170	2110	2125	2080	2117	2080	2100	2110	2140
Gordon sand	2210	2240	2180	2200	2150	2200	2130	2150	2120	2140	2150	2175
Fourth sand	2260	2285	2255	2280	2255	2290	2200	2220	2200	2215	2200	2225
Fourth "A" sand							2250	2300			2250	2270
Fifth sand	2300	2340	2320	2340	2340	2350	2320	2340	2280	2310	2290	2330
Fifth "A" sand	2350	2375			2390	2405	2370	2390	2360	2380	2370	2390
First Bayard sand	2395	2410			2425	2435	2430	2440	2415	2425	2430	2450
Second Bayard sand	2415	2430	2425	2435	2450	2490	2490	2500			2470	2500
Third Bayard sand	2455	2470	2505	2520	2510	2520			2525	2535	2520	2540
Elizabeth sand	2560	2570							2580	2590		
Warren sand			2730	2740								

TABLE VIII

GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS ABOVE AND BELOW THE UPPER FREEPORT COAL—INDIANA COUNTY

System / Series / Formation	Name of Formation	Conemaugh Township (153) Top	Bottom	Young Township (154) Top	Bottom	Armstrong Township (155) Top	Bottom	Washington Township (156) Top	Bottom	South Mahoning Township (157) Top	Bottom	West Mahoning Township (158) Top	Bottom	Burrell, Black Lick and Center Townships (159) Top	Bottom	White Township (160) Top	Bottom	Rayne and Greene Townships (161) Top	Bottom	East Mahoning Township (162) Top	Bottom	North Mahoning Township (163) Top	Bottom	Grant and Canoe Townships (164) Top	Bottom	Brush Valley and Cherry Hill Townships (165) Top	Bottom
Carboniferous; Pennsylvanian; Pittsburgh; Monongahela	Pittsburgh coal	735		715																							
Conemaugh	Elk Lick coal			480																							
	Bakerstown coal	175		300										190								200					
	Brush Creek coal	150		130						120																	
	Mahoning coal	70		60						50						80				65		60					
Pottsville; Allegheny	Upper Freeport coal	0		0		0		0		0		0		0		0		0		0		0		0		0	
	Lower Freeport coal	75		55		60		60		60				60		70		60		50		50				55	
	Upper Kittanning coal			120		120		115		125				100		115		120		100		100					
	Middle Kittanning coal			160		185		160						160		170		185		130		140		150			
	Lower Kittanning coal			190		215		215		200		200		210		215		235		205		215		210		215	
	Vanport limestone			230	250			270	290			240	250					265	275	255	265	260	270			250	260
Beaver River	Clarion coal					300				285				270		280		305		280		280		270			
	Craigsville coal													320		310											
	Brookville coal			350										340		350											
	Salt sand	190	230	250	390	230	330			300	450	260	500			360	410			360		290	440				
	Mercer coal			400						390				410		420											
	Maxton sand	445	465	440	485							505	550			460	500				485	440	500				
Mississippian; Mauch Chunk; Mauch Chunk	Little lime																										
	Pencil Cave																										
Pocono; Burgoon	Big lime																	480	500								
	Big Injun sand	470	850	500	790	400	860	420	750	500	800	550	820	450	870	510	840	500	800	500	740	500	770	410	750	390	800
Cuyahoga	Squaw sand	925	955	810	1000	900	970	830	880	860	910	880	910	890	950			850	950			790	890	900	960	850	945
Berea	Second gas sand	1030	1070	1060	1100	1000	1095	1010	1080	920	1030	950	1090	1030	1110	1030	1070	1040	1100	940	1050	920	1050	990	1100	975	1075
	Murrysville sand	1140	1215	1110	1220	1115	1185	1120	1160	1050	1150	1125	1210	1120	1210	1080	1200	1120	1210	1090	1200	1065	1160	1110	1180	1085	1100
	Hundred-foot sand	1235	1340	1230	1340	1200	1305	[illegible]	1270	1180	1300	1230	1335	1220	1320	1210	1310	1230	1335	1220	1310	1170	1350	1210	1310	1215	1325
	Thirty-foot sand			1350	1385	1325	1360	[illegible]	1330	1370	1420	1350	1400	1360	1390	1350	1390	1360	1410	1330	1360	1360	1420	1370	1400	1385	1405
Devonian; Upper; Catskill	Snee sand	1400	1420	1440	1460	1405	1425	1410	1425			1450	1480	1420	1450					1430	1450	1470	1490	1450	1500		
	Gordon stray sand	1505	1535	1570	1585									1570	1580	1600	1620			1485	1580	1530	1550	1530		1640	1665
	Gordon sand	1595	1625							1640	1650			1700	1720	1710	1730			1680	1710	1700	1720		1640	1715	1755
	Fourth sand	1655	1675	1710	1730	1650	[illegible]	1735	1755	1720	1750	1780	1800			1790	1810	1770	1795	1730	1780	1745	1760				
	Fifth sand	1705	1745	1760	1790	1835	[illegible]	1850	1860	1820	1840			1870	1890	1850	1870	1830	1860	1880	1900	1810	1850	1800	1840	1810	1815
Middle; Chemung	First Bayard sand	1835	1850	1880	1900	1880	[illegible]			1900	1935			1910	1930	1890	1920			1910	1930	1900	1940				
	Second Bayard sand					1930	[illegible]																				
	Elizabeth sand			1900	2010															2000	2050			2030	2060		
	First Warren sand			2120	2130			2195	2220	2080	2110			2150	2180			2150		2170	2200	2040	2100	2120	2140	2000	2085
	Second Warren sand			2290	2310	2370	[illegible]			2250	2270	2240	2290	2230	2260				2340	2260	2300	2235	2280	2200	2260	2150	2170
	Third Warren sand	2365	2410	2400	2415	2485	[illegible]			2450	2470			2375	2390	2450	2470			2390	2405	2340	2380	2370	2410	2375	2440
	Speechley stray sand	2500	2540	2510	2530	2545	[illegible]			2520	2580	2600	2650	2540	2570	2560	2595	2490	2505	2460	2530	2490	2540	2465	2550	2560	2620
	Speechley sand	2560	2610	2560	2610	2635	[illegible]	2595	2635	2650	2680			2620	2650	2635	2675	2570	2625	2590	2630	2635	2670	2600	2650		
	Tiona sand	2660	2680	2710	2735	2740	[illegible]			2710	2750	2750	2780	2730	2750	2780	2800	2720	2770	2670	2760	2730	2760	2720	2760	2760	2800
	First Balltown sand			2780	2800	2845	[illegible]	2800	2830	2840	2860	2825	2845	2800	2820			2810	2840	2790	2830			2810	2850	2840	
	Second Balltown sand			2840	2860					2900	2930	2890	2930			2845	2885	2850	2915	2850	2870	2840	2920				2930
	First Sheffield sand	2970	3000	2980	3000	2930	[illegible]			3020	3040	2960	2970	2960	2990			2975	3020	2950	2980	2960	3000	2935	2950	2950	2990
	Second Sheffield sand			3040	3080	3060	[illegible]	3030	3050	3090	3100	3070	3080							3000	3060			2985	3025	3020	3060
	First Bradford sand			3130	3200	3115	3190	3180	3200	3200	3220	3130	3170	3090	3140	3100	3150	3060	3100	3090	3110	3110	3145	3050	3110		
	Second Bradford sand	3100	3160	3250	3280							3220	3230					3160	3210	3150	3240	3210	3250	3190	3240		
	Third Bradford sand					3345	3400	3320	3340	3390	3420	3285	3315							3290	3310			3270	3340		
Lower; Portage	First Kane sand					3510	[illegible]											3345	3360								
	Second Kane sand																										
	Third Kane sand																										
	First Elk sand																			3720	3750						
	Second Elk sand																			3770	3805						
	Third Elk sand																			3975	3995						
	Sand																			6180	6230						
	Sand																			6540	6565						
	Sand																			6910	7040						

TABLE IX

GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS BELOW THE UPPER FREEPORT COAL—JEFFERSON COUNTY

System	Subsystem	Series	Group	Name of Formation	Potter Township (166) Top	Bottom	Ringgold Township (167) Top	Bottom	Beaver Township (168) Top	Bottom	Clover Township (169) Top	Bottom	Union Township (170) Top	Bottom	Perry Township (171) Top	Bottom	Oliver Knox and McCalmont Townships (172) Top	Bottom	Rose Township (173) Top	Bottom	Young Township (174) Top	Bottom	Pine Creek Township (175) Top	Bottom
Carboniferous	Pennsylvanian	Allegheny		Upper Freeport coal	0		0		0		0		[illegible]		0		0		0		0		0	
				Lower Freeport coal											50				50		50			
				Upper Kittanning coal					90										110		100			
				Middle Kittanning coal					110		120										150			
				Lower Kittanning coal			200		200		200				200				200		205			
				Vanport limestone	240	250	250	260	240	250	230	240	250		225	235	230	240	230	250	220	240	240	250
		Pottsville	Beaver River	Clarion coal			285		260		280				270						260			
				Craigsville coal	320				310		330										290			
				Brookville coal					350										370					
				Salt sand																	320	340		
	Mississippian	Mauch Chunk	Mauch Chunk	Little lime																				
				Pencil Cave																				
		Pocono	Burgoon	Big Injun sand	380	750	430	780	420	640	350	760	420		370	710	390	840	400	820	350	750	460	
			Cuyahoga	Squaw sand			825	855	850	960	810	890		900	875	950			840	870	790	850		900
			Berea	Second gas sand			900	1005	985	1060	955	980	950	1025	965	1030	940	1040	960	1010	900	950	930	955
				Murrysville sand	1110	1195	1085	1155	1100	1180	1030	1110	1065	1185	1040	1120	1180	1280	1070	1170	1020	1150	1050	1160
Devonian		Upper	Catskill	Hundred foot sand	1220	1245	1260	1310	1200	1305	1120	1250	1205	1300	1185	1285	1240	1310	1180	1290	1170	1290	1180	1300
				Thirty-foot sand	1330	1340	1315	1355	1315	1325	1300	1325	1315	1345			1355	1385	1310	1315	1330	1365		
				Snee sand			1380	1405	1375	1395							1400	1425						
				Gordon stray sand			1445	1470							1490	1545					1435	1460		
				Gordon sand					1485	1495	1515	1525					1595	1650	1610	1630	1650	1670	1660	1690
				Fourth sand					1725	1745	1650	1680			1700	1710	1760	1780						
				Fifth sand			1780	1820	1795	1815			1740	1770	1760	1780	1800	1820			1785	1800	1780	1820
		Middle	Chemung	First Bayard sand							1800	1820												
				Elizabeth sand					1965	1980											1940	1980		
				First Warren sand																	2030	2050	2000	2040
				Second Warren sand			2180	2210	2130	2190					2170	2200					2180	2200	2130	2140
				Third Warren sand					2370	2390			2350	2370	2300	2330	2250	2280			2380	2390	2230	2260
				Speechley stray sand			2460	2510	2445	2475	2390	2415	2475	2490	2420	2460	2420	2410	2380	2410	2435	2470	2390	2440
				Speechley sand	2525	2565	2550	2590	2485	2585	2500	2525	2575	2615	2490	2530	2460	2550	2440	2480	2490	2525	2470	2510
				Tiona sand			2670	2700	2695	2730	2575	2600			2570	2590	2580	2670	2570	2600	2600	2630		
				First Balltown sand	2735	2765					2700	2730	2725	2755	2680	2730	2700	2730	2620	2670	2675	2730	2670	2740
				Second Balltown sand			2780	2810	2780	2820			2800	2820	2760	2780	2790	[illegible]					2770	2790
				Sheffield sand			2910	2940	2925	2985	2815	[illegible]	2870	2920	2850	2900	2840	2900	2770	2820			2830	2860
				First Bradford sand			3015	3035	3065	3080	2990	[illegible]			2960	3010	2940	3020	2950	2990			2880	2980
				Second Bradford sand			3090	3110	3130	3150	3055	[illegible]	3070	3100	3050	3080							3070	3090
				Third Bradford sand			3190	3205	3165	3200	3105	[illegible]			3120	3140	3100	3130	3110	3130				
		Lower	Portage	First Kane sand			3280	3290	3260	3280	3200	[illegible]	3220	3240	3180	3210	3180	3200	3190	3230			3150	3190
				Second Kane sand					3375	3415	3275	[illegible]	3300	3320			3250	3270					3380	3400
				Third Kane sand							3350	[illegible]	3430	3450									3780	3940
				First Elk sand																			4080	4140
				Second Elk sand																			4280	4320
				Third Elk sand																				

TABLE X

GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS ABOVE AND BELOW THE PITTSBURGH COAL—WASHINGTON COUNTY

Name of formation	West Finley Township (19) Top	Bottom	Donegal and Blaine Townships (20) Top	Bottom	Independence and Cross Creek Townships (21) Top	Bottom	Jefferson Township (22) Top	Bottom	Hanover Township (23) Top	Bottom	Smith Township (24) Top	Bottom	Robinson Township (25) Top	Bottom	East Finley and Buffalo Townships (26) Top	Bottom	Hopewell and Mt. Pleasant Townships (27) Top	Bottom
Washington coal																		
Waynesburg "B" coal															430			
Upper Waynesburg coal																		
Middle Waynesburg coal																		
Lower Waynesburg coal	300		300												300			
Uniontown coal	225														230			
Mapletown coal	100		90		85										100			
Redstone coal																		
Pittsburgh coal	0		0		0		0		[illegible]		0		0		0		0	
Morgantown sand	155	215	220	270	250	300	120	[illegible]							180	240	150	200
Bakerstown coal							320											
Little Dunkard sand	375	420					380	[illegible]	400	430					370	400		
Brush Creek coal					410												400	
Mahoning coal					460												470	
Big Dunkard sand	500	560					470	[illegible]			510	550			480	560	520	560
Upper Freeport coal	[illegible]				550		540		[illegible]		550		550		565		565	
Lower Freeport coal					600		600		[illegible]		580		620				605	
Upper Kittanning coal					650		650		665		680		665				650	
[illegible] sand	700	735	600	710			660	[illegible]	700	765								
Middle Kittanning coal					680				720		710		720				700	
Lower Kittanning coal	715				750		710		765		760		760		780		745	
First salt sand	750	815													785	820	780	800
Clarion coal					815		780		825				840				805	
Second salt sand	840	890					830	[illegible]			840				850	890	820	840
Brookville coal							900										865	
Third salt sand	910	1010	940	1020	850	990	910	960	910	960			915		930	1030	870	1000
Mercer coal									960									
Maxton sand							970	[illegible]	990	1040		1000		1030	1050	1090		
Little lime	1055	1065															1020	1035
Big lime	1070	1150	1070	1100	1000	1040	1010	[illegible]	1055	1085	1000	1020	1035	1060	1100	1130	1070	1100
Big Injun sand	1150	1410	1100	1400	1040	1255	1035	[illegible]	1085	1365	1020	1330	1060	1365	1130	1400	1100	1350
Squaw sand	1550	1610	1460	1510	1350	1380	1330	[illegible]	1440	1460	1390	1420	1450	1550	1490	1540	1380	1420
Second gas sand	1705	1705			1475	1490									1720	1760	1575	1615
Murrysville sand	1780	1820	1710	1785	1570	1500	1605	[illegible]	1600	1625	1650	1680	1690	1720	1770	1820	1650	1720
Gantz sand	1885	1920	1815	1825	1720	1760			1705	1730					1860	1890	1800	1815
Fifty-foot sand	1935	1955	1870	1920	1815	1825	1800	1815	1875	1900	1855	1870	1930	1050	1930	1950	1830	1875
Thirty-foot sand	1970	2000			1905	1930	1900	1910	1920	1930	1070	1975	2035	2060	1970	1995	1920	1935
Snee sand	2010	2025																
Gordon stray sand	2050	2070											2080	2090	2030	2060	2000	2025
Gordon sand	2110	2125	2050	2065	2035	2045	1970	1980	1985	2060			2130	2140	2080	2110	2050	2065
Fourth sand	2145	2160	2100	2105			1990	2005							2130	2160	2100	2120
Fourth "A" sand							2055	2065	2120	2125								
Fifth sand	2210	2230	2130	2160											2180	2200	2160	2170
Fifth "A" sand							2080	2090	2145	2175							2200	2210
First Bayard sand																		
Second Bayard sand									2225	2230					2240	2270	2250	2265
Third Bayard sand																		
Elizabeth sand															2340	2350		
Warren sand													2370	2375	2455	2465	2390	2405
Speechley stray sand			2660	2680	2550	2565	2270	2290										
Speechley sand																		
Tiona sand									2800	2840								
Balltown sand					3225	3230												
Sheffield sand																		
First Bradford sand																		
Elk sand													3565	3575				
— —													4225	4295				
Corniferous lime													6133	6170				
Niagara limestone													7165	7173				

Name of formation	Morris Township (28) Top	Bottom	North and South Franklin Townships (29) Top	Bottom	Canton Township (30) Top	Bottom	Chartiers Township (31) Top	Bottom	Cecil Township (32) Top	Bottom	Amwell Township (33) Top	Bottom	South Strabane Township (34) Top	Bottom	North Strabane Township (35) Top	Bottom	Peters Township (36) Top	Bottom	West Bethlehem Township (37) Top	Bottom
Washington coal	490		[illegible]																	
Waynesburg "B" coal	450										440		450							
Upper Waynesburg coal																				
Middle Waynesburg coal	360		375								380								390	
Lower Waynesburg coal	300		310								310		310						335	
Uniontown coal			225																270	
Mapletown coal	100		105								110		105						115	
Redstone coal																			65	
Pittsburgh coal	0		0		0		0		0		0		0		0		0		0	
Morgantown sand	180	230	170	250			200	220	140	190	180	240	185	275	190	[illegible]	[illegible]	190	180	230
Bakerstown coal	360						350												380	
Little Dunkard sand	365	410	300	360			400	420			460	500	400	500	420	[illegible]	[illegible]	130	385	440
Brush Creek coal																				
Mahoning coal			450														[illegible]		530	
Big Dunkard sand	470	560	400	570			500	540	510	580			550	610	510	[illegible]	[illegible]	565	530	600
Upper Freeport coal	570		580				580				565		610		610		[illegible]		600	
Lower Freeport coal							620										[illegible]		650	
Upper Kittanning coal	650						660										[illegible]		705	
[illegible] sand	710	760	720	765	670	710	665	730			690	730			730	770	[illegible]	750	710	780
Middle Kittanning coal	710		710				730		700		740		790						745	
Lower Kittanning coal	780		770				780										770		790	
First salt sand			775	820	780	830	785	850	830	850	820	870	820	860			[illegible]	900	810	880
Clarion coal	800		825				850						870						850	
Second salt sand	880	970	830	900	850		860		890	940	910	970	900	1000			915	1000	890	1000
Brookville coal																				
Third salt sand	1000	1020	930	1020		990		1010	1015	1050	980	1050			[illegible]	1010	1010	1040	1010	1070
Mercer coal																				
Maxton sand	1060	1090	1050	1070			1020	1040			1070	1100					[illegible]	1100	1080	[illegible]
Little lime											1100	1110	1090	1100	1085	1095	1105	1120	1130	1145
Big lime	1110	1160	1110	1140	1030	1070	1060	1110			1120	1170	1110	1145	1100	1150	[illegible]	1180	1155	1215
Big Injun sand	1160	1440	1140	1440	1070	1370	1110	1350	1160	1390	1170	1470	1145	1400	1150	1400	[illegible]	1430	1215	1130
Squaw sand	1490	1530	1500	1520	1400	1490	1415	1500	1440	1460	1500	1550			1440	1510	[illegible]	1580	1520	1655
Second gas sand			1730	1800					1720	1740	1745	1785	1660		1670	1715	[illegible]	1785	1780	1810
Murrysville sand	1735	1835	1820	[illegible]	1600	1680	1610	1720			1810	1850		1790			[illegible]	1875	1855	1910
Gantz sand	1890	1920	1850	[illegible]	1740	1760	1800	1850	1860	1890	1875	1910	1870		1850		[illegible]	1930	1975	2025
Fifty-foot sand	1940	2000	1890	[illegible]	1780	1830	1840	1900	1900	1985	1920	1990		1915		1950	[illegible]	2010	2035	2070
Thirty-foot sand	2035	2070	1990	2020	1850	1910	1960	1980	2015	2025	2030	2060	1990	2030	1990	2030	[illegible]	2095	2110	2130
Snee sand																			2145	2160
Gordon stray sand	2080	2100	2050	2095	1950	2000	2000	2030	2100	2115	2095	2130	2050	2090	2070	2095	[illegible]	2165	2185	2210
Gordon sand	2110	2170	2100	[illegible]	2020	2040	2040	2060	2110	2160	2140	2165	2095	2130	2100	2130	[illegible]	2220	2230	2260
Fourth sand	2195	2225	2150	[illegible]	2060	2090	2100	2130	2180	2200	2175	2210	2140	2175	2150	2190	2240	[illegible]	2285	2305
Fourth "A" sand																				
Fifth sand	2250	2290	2225	2250	2120	2110	2160	2190	2210	2255	2240	2255	2200	2210	2210	2240	2290	2310	2340	2350
Fifth "A" sand											2275	2290								
First Bayard sand																				
Second Bayard sand					2170	2185														
Third Bayard sand											2380	2400					2410	[illegible]	2135	2150
Elizabeth sand	2390	2400					2320	2330			2470	2490							2500	2510
Warren sand			2460	2465													[illegible]	[illegible]	[illegible]	2540
Speechley stray sand																	3070	3100		
Speechley sand																				
Tiona sand																				
Balltown sand																	[illegible]	3220		
Sheffield sand																	3500	3520		
First Bradford sand																				

Name of formation	Somerset Township (38) Top	Bottom	Nottingham Township (39) Top	Bottom	Union Township (40) Top	Bottom	[illegible] Township (41) Top	Bottom	East Bethlehem Township (42) Top	Bottom	Centerville Borough and East Pike Run Township (43) Top	Bottom	[illegible] and West Pike Run Townships (44) Top	Bottom	[illegible] (45) Top	Bottom	[illegible] (46) Top	Bottom	[illegible] (47) Top	Bottom
Washington coal							180						180							
Pittsburgh coal	0		0		[illegible]		[illegible]				0		[illegible]		[illegible]					
Morgantown sand	190	250																		
Little Dunkard sand	[illegible]	425	140	475																
Big Dunkard sand	555	610	570	600																
Upper Freeport coal	615		600																	
Lower Freeport coal			650																	
[illegible] sand	720	770	710	755																
Lower Kittanning coal			800																	
First salt sand	810	[illegible]	900	940																
Third salt sand	1055	1120	1070	1100																
Maxton sand			1105	1130																
Little lime	1150	1165	1130	1110			1170	1180	[illegible]	1180	1180	[illegible]	1155	1170	1115	1170	1170	1185	1200	1226
Big lime	1170	1210	1160	1195	1190	1250	1185	1225	[illegible]	[illegible]	1210	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Big Injun sand	1210	1165	1195	1450	1250	1540	1225	1540	[illegible]	[illegible]	1510	1210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Squaw sand	1540	1620	1170	1580	1570	1650	1610	1700	[illegible]	1700	1620	1680	1560	1675	1560	1660	1540	[illegible]	1610	1720
Second gas sand	1745	1828	1705	1800	1840	1885	1800	1810	1800	1840	1845	1875	1825	1850	1790	1828	1780	1840		
Murrysville sand	1858	1908	1830	1875	1950	1970	1930	1945			1930	1960	1900	1925	1870	1910	1880	1910	1920	1980
Gantz sand	1970																			
Fifty-foot sand		2045																		
Thirty-foot sand		2130																		
Gordon stray sand	2150	2170																		
Fifth sand	2335	2370																		

TABLE XI

GENERAL SECTIONS SHOWING DEPTH OF VARIOUS HORIZONS BELOW THE PITTSBURGH COAL—WESTMORELAND COUNTY

System	Subsystem	Series	Formation	Name of Formation	Rostraver Township (57) Top	(57) Bottom	South Huntingdon Township (58) Top	(58) Bottom	Sewickley Township (59) Top	(59) Bottom	North Huntingdon Township (60) Top	(60) Bottom	Penn Township (61) Top	(61) Bottom	Franklin Township (62) Top	(62) Bottom	Washington Township (63) Top	(63) Bottom	Upper Burrell Township (64) Top	(64) Bottom
Carboniferous	Pennsylvanian	Pittsburgh	Monongahela	Pittsburgh coal	0		0		0		0		0		0		0		0	
			Conemaugh	Bakerstown coal									420		410				420	
				Little Dunkard sand	370	440	370	410												
				Brush Creek coal	445										485		490		490	
				Mahoning coal							535		500		550		550		545	
				Big Dunkard sand	465	520	500	580							610	630				
			Allegheny	Upper Freeport coal	575		590		580		580		625		660		670		650	
				Lower Freeport coal	645				645		640		665		750		720		705	
				Upper Kittanning coal	705						705		750		800		770		780	
				Middle Kittanning coal	780				760		775				850		850		810	
				First gas sand	790	840	740	820	700	760							850	885		
				Lower Kittanning coal	840		820		800		820		850		910		885		885	
				Vanport limestone											930	940	930	940	910	925
		Pottsville	Beaver River	First salt sand	900	925	825		805	880	850	[illegible]					890	930		
				Clarion coal									890		950		960			
				Second salt sand	945	1040		990	890	1000	1000	[illegible]	940	1010	960	1070	965	1030	990	1020
				Brookville coal	1040				1010		1075		1010						1020	
				Third salt sand	1055	1080	1040		1015	1085	1085	[illegible]	[illegible]	1125	1100	1150	1090		1030	1115
				Maxton sand	1185	1195		1180										1190	1140	1175
	Mississippian	Mauch Chunk	Mauch Chunk	Little lime																
				Pencil Cave																
			Burgoon	Big lime	1205	1240	1190	1230	1190	1210			1200	1250	1190	1220	1200	1240	1185	1210
				Big Injun sand	1210	1490	1230	1530	1210	1540	1215	[illegible]	1250	1565	1220	1570	1240	1510	1210	1510
		Pocono	Cuyahoga	Squaw sand	1530	1605	1555	1645	1560	1735	1600	[illegible]	1645	1725	1600	1760	1620	1655	1550	1650
			Berea	Second gas sand	1790	1850	1760	1780	1765	1800			1850	1885	1840	1880	1725	1785		
				Murrysville sand	1875	1990	1890	1940	1875	1965	1900	[illegible]	1920	2050	1920	2030	1855	1950	1835	1980
Devonian	Upper			Hundred-foot sand	2005	2130	1970	2070	1095	2095	2035	[illegible]	2060	2180	2040	2150	1960	2035	1990	2100
				Thirty-foot sand	2150	2180	2090	2130	2115	2150	2165	2200	2210	2235	2160	2190	2055	2085	2110	2140
			Catskill	Snee sand									2250	2275	2220	2230	2135	2145		
				Gordon stray sand	2210	2220	2260	2270					2300	2325	2290	2305				
				Gordon sand	2285	2310	2350	2360					2335	2385	2340	2360	2330	2350		
				Fourth sand			2430	2440					2430	2460	2410	2440	2445	2470	2410	2435
				Fifth sand	2440	2465	2485	2500	2455	2475	2485	[illegible]			2480	2510	2480	2505	2450	2490
	Middle		Chemung	First Bayard sand													2525	2555		
				Second Bayard sand	2525	2535	2530	2560	2530	2565			2545	2585	2560	2580			2555	2600
				Third Bayard sand	2580	2590					2775	2805	2625	2655	2610	2625	2615	2645		
				Elizabeth sand	2670	2690	2655	2685							2660	2680				
				First Warren sand			2800						2905	2925	2990	3010				
				Second Warren sand	2880	2940		2940					3035	3055						
				Third Warren sand	3095	3125							3185	3205	3140	3190				
				Speechley stray sand			3210	3210					3205	3315	3270	3295	3250	3275	3195	3220
				Speechley sand	3300	3310	3290	3310	3305	3350	3350	[illegible]	3380	3410	3350	3385	3355	3400	3240	3300
				Tiona sand			3440	3450					3535	3555	3490	3505	3500	3520	3410	3440
				First Balltown sand									3665	3690	3590	3605			3600	3650
				Second Balltown sand							3580	3590			3660	3675				
				Sheffield sand									3750	3765						
				First Bradford sand	3800	3810	3810	3820					3800		3790	3810	3750	3800		
				Second Bradford sand					3860	3870	3910	3920		3930	3880	3950	3875	3935	3870	3930
				Third Bradford sand	3960	3970							3940	3960	4030	4050				
			Portage	First Kane sand																
				Second Kane sand																
				Third Kane sand																
				Elk sand group																
				Sand																
	Lower		Oriskany	Corniferous lime																
				Oriskany sand																
[illegible]ian	Cayuga and Ontario		Oneida and Salina	Stormville sand																
				Sand																

Formation	Name of Formation	Lower Burrell Township (65) Top	(65) Bottom	Allegheny Township (66) Top	(66) Bottom	Hempfield Township (67) Top	(67) Bottom	Salem Township (68) Top	(68) Bottom	Loyalhanna Township (69) Top	(69) Bottom	Bell Township (70) Top	(70) Bottom	Unity Township (71) Top	(71) Bottom	Derry Township (72) Top	(72) Bottom	Ligonier Township (73) Top	(73) Bottom
Monongahela	Pittsburgh coal	0		0		0		0		0		0		0		0		0	
Conemaugh	Bakerstown coal			435		410						390							
	Little Dunkard sand																		
	Brush Creek coal			510		515						540		490					
	Mahoning coal			570				545		600		600		540					
	Big Dunkard sand					580	630												
Allegheny	Upper Freeport coal	650		630		630		650		650		670		620					
	Lower Freeport coal	700		690		690		715		730		730		670					
	Upper Kittanning coal			745		740		755				780		720		720			
	Middle Kittanning coal			800		780		805				820		760					
	First gas sand											825	870						
	Lower Kittanning coal			845		820		870				875		810		810			
	Vanport limestone			850	900							895	900			840	850		
Beaver River	First salt sand					870		940				930		880		850			
	Clarion coal																		
	Second salt sand	1020	1100	945	995	890	1010					970	1060						
	Brookville coal					1010													
	Third salt sand			1035	1065	1085	1145	1135	1240			1070	1165	1060	1150		1190		
	Maxton sand																		
Mauch Chunk	Little lime																		
	Pencil Cave																		
Burgoon	Big lime	1200	1250			1225	1255	1250	1280	1270	1300	1200	1230	1175	1210	1200	1230	1360	1430
	Big Injun sand	1250	1600	1220	1540	1255	1590	1280	1650	1300	1650	1230	1525	1210	1500	1230	1500	1130	1680
Cuyahoga	Squaw sand	1660	1780	1610	1670							1585	1685	1575	1700			1770	1875
Berea	Second gas sand	1800	1820	1740	1780	1815	1885	1820	1880	1860	1890	1715	1765	1780	1840	1720	1760	1985	1995
	Murrysville sand	1890	1970	1815	1920	1915	2000	1920	2035	1920	1980	1880	1970	1865	1955	1860	1990	2015	2085
	Hundred-foot sand	1990	2110	1950	2090	2010	2105	2055	2165	2000	2160	2000	2085	1970	2085			2255	2260
	Thirty-foot sand	2140	2170	2130	2160	2115	2170	2180	2235	2190	2230	2130	2155						
Catskill	Snee sand	2220	2270																
	Gordon stray sand	2310	2330	2250	2290	2240	2250			2280	2300	2250	2270						
	Gordon sand	2350				2315	2345					2345	2360						
	Fourth sand		2420			2425	2450	2445	2485	2430	2440			2445	2470			2660	2680
	Fifth sand	2460	2500	2450	2495	2520	2540	2515	2540	2525	2530	2510	2520	2495	2505			2695	2700
Chemung	First Bayard sand											2565	2580	2535	2595	2560	2615	2745	2765
	Second Bayard sand			2555	2580	2575	2615	2580	2600	2580	2600	2610	2630						
	Third Bayard sand					2660	2675	2640	2670	2680						2650	2670		
	Elizabeth sand					2720	2730	2710	2730		2720			2735	2745				
	First Warren sand					2850	2870												
	Second Warren sand													3070	3095				
	Third Warren sand			3120	3140														
	Speechley stray sand			3200	3220	3250	3275	3260	3285	3260	3280	3275	3310	3260	3285			3460	3480
	Speechley sand	3300	3350	3265	3300	3340	3375	3350	3380	3330	3370	3350	3375	3350	3385	3370		3505	3550
	Tiona sand	3460	3480	3465	3495	3500	3515	3510	3520	3140	3460	3455	3525	3450	3495		3515	3675	3685
	First Balltown sand	3610	3630			3600	3610			3560	3580	3610	3655	3600	3640			3845	3850
	Second Balltown sand									3600	3620								
	Sheffield sand					3730	3760	3740	3785			3730	3740	3765	3825			4035	4045
	First Bradford sand	3840	3860	3770	3815	3820	3845					3845	3860					4085	4100
	Second Bradford sand	3930	3950	3845	3900	3885	3900			3870	3900	3875	3905	3905	3925			4120	4230
	Third Bradford sand			3955	3965	3975	4000	3920	4000	3930	4010			3965	3970				
Portage	First Kane sand									4050	4060			4070	4075			4370	4430
	Second Kane sand																	4470	4490
	Third Kane sand																	4565	4570
	Elk sand group																	4725	5130
	Sand																	6840	6865
Oriskany	Corniferous lime																	8435	8465
	Oriskany sand																	8465	8860
Oneida and Salina	Stormville sand																	8900	9150
	Sand																	9300	9475

SEWAGE DISPOSAL AND GARBAGE INCINERATION FOR GREENVILLE, PA.*

By J. F. Laboon†

INTRODUCTION

It is not often that the engineer gets an opportunity to design a garbage incinerating plant in conjunction with a sewage disposal plant for the same client, but such was the case at Greenville, Pa., with the result that operation of both plants will be possible with less public nuisance and better economy by the location of the plants contiguous to one another.

SEWAGE DISPOSAL PLANT

Existing Sewage Disposal Plant. The old plant consists of coarse screens, two Imhoff tanks, an open sludge bed, a chlorinating tank and chlorinator building. This plant was designed by the author's firm in 1914 and 1915, and was placed in operation in 1916. The author served on the original designs and as supervising engineer of construction, operating from the main office at Pittsburgh.

The existing Imhoff tanks are of circular, flowing-through type, each with double sludge compartments. These tanks were designed in accordance with popular practice at the time of construction. The detention period was made 1.7 hours at the rate of 1,000,000 gallons a day, while the sludge compartments were based on Allen's formula, which gave approximately one cubic foot per capita. This value is considered too small in present-day practice, which dictates that the sludge capacity in Imhoff tanks treating domestic sewage shall be not less than two cubic feet per capita. The sludge bed was built on the basis of one square foot per capita, but because the sludge bed was located below average flood stages of the river, this capacity was not realized at all times.

Chlorination of the plant effluent was carried on for several years, but has been abandoned during the last five years or more, inasmuch as the state Department of Health has not required it.

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The operating results obtained with the old plant are remarkable, particularly from the standpoint of sludge digestion. Most Imhoff tanks are subject to operating troubles, such as foaming, and excessive scum formation, but the Greenville tanks have been entirely free from foaming and have not been overburdened with excessive scum formation, in spite of the fact that very little attention was given the plant throughout all of the years of its operation. The concrete in the Imhoff tanks and in the screen chamber, is as good as the day it was put in, which is an unusual condition for concrete after years of exposure to sewage and the elements.

The screenings from the coarse screen have been disposed of by dumping on the garbage dump adjacent to the sewage disposal plant, or by burying.

Due to the fact that roof drains have been connected to the sanitary sewer system in great numbers (although prohibited by law) the sewage disposal plant has been subjected to extraordinarily heavy flows whenever heavy storms occurred, and sometimes it became so great as to fill the 24-inch outfall sewer to the plant and cause the sewage to leap the coarse screens and land directly in the Imhoff tanks. While the silt carried in storm flows is generally detrimental to the successful operation of an Imhoff tank, this was not experienced at Greenville. However, the general consequences created by such conditions at the sewage disposal plant, and the fact that the heavily charged sewers backed up the sewage into some of the cellars uptown, were sufficient reasons for adopting relief measures in the way of overflow weirs located at opportune points.

Design. The present population of Greenville is estimated at 10,000, with 2700 families resident within the borough. The sewer system consists of approximately 20 miles of sewers ranging from eight-inch to 24-inch, including the outfall sewer to the plant. About eight miles of these sewers were designed by the author's firm and built at the same time as the old sewage disposal plant. These sewers serve approximately 2100 sewer connections. The water consumption at the present time is approximately 500,000 gallons a day, all of which is metered.

The present sewage flow averages about 850,000 gallons a day. The improved sewage disposal plant will have a capacity of 1,500,000

gallons a day. The sludge capacity is based on a population of 12,000. Complete design data are as follows:

Average flow	1,500,000 gallons a day.
Detention period	2 hours.
Sludge compartments	2 cubic feet per capita; 24,000 cubic feet.
Sludge bed	4250 square feet.
Sludge ejector	50 gallons a minute.
Time of filling one section of sludge bed	2 hours.

New Improvements. The new improvements consist of a rectangular Imhoff tank, a mechanically cleaned screen chamber, a glass-covered sludge bed, a sludge-pumping station, and two overflow weir manholes—one located at the foot of Race Street and the other at the sewage disposal plant.

The new screens are designed for mechanical cleaning, and are equipped with one-inch openings. The screenings will be drained on a screen board and hauled away to the garbage incinerating plant and incinerated with the garbage. This screen will be in continuous operation and will require only incidental supervision. It is of the latest oscillating type, as manufactured by the Dorr Company.

The new Imhoff tank has been designed with an extraordinarily large sludge capacity in order that the sum of the sludge capacities of the old and the new tanks shall be equivalent to two cubic feet per capita. The sludge from the old tanks will be pumped to the sludge compartment of the new tank from time to time as conditions may require, with special reference to optimum digestion of the sludge. In this way it is hoped to maintain a balance of work to be done in sludge digestion in all tanks. By this means, lime may be applied for the correction of the pH of the sludge whenever it is deemed advisable to do so. The new tank is covered with a permanent concrete roof and equipped for gas collection. The gas is piped to the garbage incinerator where it will be used as fuel for incinerating garbage.

A new sludge bed completely covered with a glass inclosure has been constructed on high ground to replace the existing low-level sludge bed. The new sludge bed is approximately 8½ feet higher than the Imhoff tanks, thus making it necessary to pump the sludge from the Imhoff tanks to the sludge bed for drying. The area of the

new bed is 4250 square feet which is deemed sufficient for a population of 12,000. The bed is divided into five compartments by means of stop planks, and is equipped with sludge carriers and walkways located above the sludge level. The effluent from the sludge beds is returned to the Imhoff tanks for resettling.

The sludge-pumping station is made necessary by the placing of the sludge bed higher than the Imhoff tanks, but in addition to this it serves as a most useful element in the transfer of sludge between the Imhoff tanks and for the mixing of ripe sludge with undigested sludge in order to promote optimum digestion. The station is equipped with a sludge ejector with a capacity of 50 gallons a minute, complete with air-compressor and air-storage tank. In the same building are located also the water well and pumping system, Venturi meter recorder and register, and switchboard for the entire plant.

The water-supply is obtained from a well drilled through the bottom of the basement of the sludge-pumping station. The water is furnished to the various units of the sewage disposal plant and to the garbage incinerating plant by means of an automatic electric pumping unit having a capacity of 10 gallons a minute.

The overflow manholes have been completed and the one located on Race Street already has relieved conditions materially in that district. The overflow from the Race Street weir reaches the Shenango River through an old sewer located under the Bessemer & Lake Erie Railroad shops. The overflow weir at the sewage disposal plant will take the remaining excess of the heavy storm flows and by-pass them around the sewage disposal plant. Inasmuch as the sewage disposal plant is located below the highest flood level, it is necessary to protect the plant from flooding by the construction of dikes completely surrounding the plant. This requires also the installation of sluice-gates to shut off the sewage to the sewage disposal plant when the river rises to a level higher than the walls of the Imhoff tanks. The entire flow at such times will be diverted to the stream. A flap gate is installed in a manhole in the outfall sewer leading from the Imhoff tanks to the river to keep the river from backing up into the tanks until a gate-valve located in this line can be closed.

A Venturi meter has been installed in the outfall sewer immediately below the Imhoff tanks. A constant and permanent record will thus be kept of the flow through the plant.

The existing chlorinating detention tank is being by-passed, inasmuch as chlorination is not now required. When not chlorinating, this tank has been a source of operating nuisance, inasmuch as it serves to settle out some of the solids which were not settled in the Imhoff tanks, thus fouling the final effluent by the putrefaction which took place in the tank. By-passing this unit will remedy this condition completely.

Costs. Bids on the new improvements were taken July 12, 1929, with the following results:

Item	Description	*Pihl & Miller, Pittsburgh	Bever & Morris, Cleveland	J. C. Speaker, Pittsburgh
2	Excavating and grading	$ 7,300	$ 8,549	$25,500
4	Concrete. Imhoff tank	20,400	17,058	20,500
5	Concrete. Sludge bed	2,400	2,098	2,500
6	Concrete. Pumping station	1,300	1,311	1,800
7	Concrete. Screen chamber	820	874	900
8A	Cement walks	310	250	225
9	Concrete steps	250	190	500
10	Sand, gravel and drains, sludge bed	1,500	1,417	2,050
11	Outside piping and miscellaneous equipment	16,800	16,445	17,500
12	Overflow manhole, Race Street	490	890	400
13	Screen equipment	2,500	2,305	3,500
14	Sludge ejector	1,400	1,320	1,800
15	Water-supply	780	644	800
17	Superstructure of sludge-pumping station	700	886	1,075
25	Electrical work	580	800	1,100
	Total of general contract	$57,530	$55,037	$80,150

27 Glass cover for sludge bed:

*Lord & Burnham, Irvington, N. Y.	$ 9,491
Pihl & Miller, Pittsburgh	13,300
J. C. Speaker, Pittsburgh	12,000
Barns Engineering Company, New York	12,341

Pihl & Miller	$57,530
Lord & Burnham	9,491
Total cost of improvements	$67,021

*Awarded contract.

The above tabulation would indicate that the contract was not awarded to the low bidder, but such was not the case, as the bid price of Pihl & Miller on both the sewage disposal plant and garbage plant, including the unit price items of extra earth and rock excavation, concrete, etc., was low by the amount of $858.

GARBAGE INCINERATING PLANT

Existing Conditions. For some years garbage has been collected by a private individual who makes a monthly charge against every householder. All of the garbage is wrapped and rubbish and tin cans are not permitted in the garbage. This garbage is hauled to the city property adjacent to the sewage disposal plant and there dumped on the surface. This has caused unsanitary conditions to prevail in this vicinity, and furthermore has served as a feeding ground for hundreds of rats. The rubbish is collected by the city once a year on a clean-up day. This rubbish is hauled to low land and dumped as fill.

Design. The best available data, as furnished by Mr. C. P. Clarke, City Engineer at Greenville, indicate that the summer yield of garbage will amount to 46 tons a week, as compared with 23 tons a week in winter. During the month of August the garbage will total 64 tons a week. It may thus be assumed that the total garbage collected is approximately 1800 tons annually, which gives a per capita production of 360 pounds a year. This figure is exceedingly high, but on the other hand the community is such as would tend to produce large quantities of garbage. The average daily amount of garbage, therefore, is six tons, which must be incinerated in eight hours of the day. The maximum daily quantity is in the month of August, when a total of 11 tons must be incinerated daily. Under these conditions it was concluded that the incinerator should have a capacity of 30 tons per 24 hours, or 10 tons per eight hours.

Plans and Specifications. No attempt was made to design the details of a garbage furnace which would serve as a model for bidding purposes, or even for construction purposes, but instead the specifications were so written as to incorporate good modern practice and certain individual requirements which each bidder was required to meet. The plans, therefore, consisted of a general-arrangement

drawing showing the location and outline of the proposed building in which the garbage furnace was to be erected.

Upon receipt of bids and letting of contracts for the garbage furnace the contractor was required to submit details of his furnace, for approval, after which the building construction details were worked out by the engineers. Then bids were requested on the foundations and building for the garbage plant, these bids being taken simultaneously with the bids on the sewage disposal plant improvements.

Certain features of the specifications are presented here as being of possible interest:

1. The furnace was to consume garbage alone without the aid of combustible rubbish.

2. The contractor was to make a guarantee as to the amount of coal required to burn a ton of such garbage.

3. The garbage was defined as consisting of 75 per cent. moisture, 21 per cent. combustible, and four per cent. non-combustible material.

4. The chimney was to be at least 100 feet high and five feet in internal diameter, completely lined with fire-brick.

5. The fire-brick was required to be of certain composition and laid in high-temperature cement.

6. Forced draft with air preheated to not less than 200 degrees was required.

7. The grate surface and charging capacity were to be ample for the service.

8. The combustion chamber was to have a capacity of at least 240 cubic feet, and was to be lined with fire-brick.

9. A heat balance was required of each bidder to show how he arrived at his coal guarantee.

10. A guarantee maintenance bond for a period of two years was to be furnished by the contractor.

11. The temperature in the furnace was to be maintained at not less than 1250 degrees F.

12. The contractor is subject to an actual performance test to be made by the engineers, when the garbage fed to the furnace is

to be weighed, analyzed, and balanced as against the coal consumption. Two tests, each of eight hours duration, will be made.

13. The contractor is not to be paid anything until his work is completed, and the furnace tested and accepted.

These are but some of the provisions of the specifications and contract. Many other details are contained in the specifications. It was most interesting to note and to experience the opposition to the engineers' specifications on the part of many of the garbage furnace bidders, because of the fact that such bidders are seldom called upon to bid on garbage furnaces which required the incineration of garbage alone without the aid of combustible rubbish. Furthermore, the furnace bidders have been accustomed to dealing with the municipal officers directly, and were unaccustomed, generally speaking, to bidding on engineers' specifications. In spite of all of the influence exerted by some of the bidders, to have the contract awarded to them on their own pet specifications, many bona fide bids were received on the basis of the engineers' specifications and the contract was thus awarded.

Letting the Incinerator Contracts. Bids were taken twice on this project, the first bids being rejected because of the failure of many of the contractors to bid wholly within the specifications. The specifications were revised and further restricted in some details, so as to require the bidders to comply with certain features of design and construction which were considered of paramount importance. It is notable that the second set of bids was, as a general rule, somewhat lower than the first set by the same contractors, in spite of the greater restrictions. A summary of the formal bids received on the first and second lettings is as follows:

Bidder	First bids	Second bids
Morse-Boulger Destructor Company	$19,207	$15,925.00
Wasteverter Furnaces, Inc.	18,500	16,267.00
Borge-Ellison Corporation	22,482	16,982.00
Superior Incinerating Company	17,000	17,000.00
Pittsburgh-Des Moines Steel Company	15,800	19,410.00
Nye Odorless Incinerator Corporation	24,700	19,683.80

Comparisons were based on the amount of coal and power consumed per ton of specified garbage, the building volume required for

proper housing of the incinerator bid upon, the time of completion, and the cost of labor required to operate the furnace. The comparisons were made on the basis of two garbage units.

On this specified basis the Wasteverter Furnaces, Inc., was the low bidder, besides having offered a first-class furnace with most excellent materials. The contract was awarded to the Wasteverter Furnaces, Inc., and the building was designed to accommodate the furnace of that company. However, some months after the letting of the contract and just prior to the completion of the superstructure for the garbage incinerating plant, the engineers were notified that the Wasteverter Furnaces, Inc., had been absorbed by the Nye Odorless Incinerator Company which then offered its circular type of furnace for acceptance by the borough and the engineers. A change from one furnace to another could prove very serious in view of the different space requirements, but in this case a few minor changes in the concrete work, particularly in the foundations for the garbage furnace, permitted the installation of the proposed furnace without detracting from the convenience of operation or the economical operation of the furnace itself. After a detailed study and inspection of the proposed furnace it was decided to permit the change with the understanding, of course, that the furnace contractor was to pay all costs involved by the change in the concrete work, steel columns, etc.

General Details. The garbage incinerating plant is a two-story building. The basement contains the garbage furnace, forced-draft fan, preheater, coal-bin, and toilet-room; and on the second floor are the charging opening, the hot-water tank, and minor accessories.

The new furnace is circular in type, 10 feet in inside diameter, and inclosed in a steel shell. The furnace is equipped with but one charging hole located in the center, thus eliminating two of the three charging holes contemplated in the original contract. This simplifies the charging of the furnace. This furnace, like that originally proposed, is equipped with a preheater, dampers in the main and by-pass flues, large combustion chamber, water heater, and other accessories, and is subject to the same tests and guarantees under all conditions of the specifications and contract.

The chimney is located at the rear of the building and is connected to the combustion chamber of the garbage furnace by one

underground and one overhead flue. The stoking doors and ash doors are located on the basement floor. The ashes are to be removed to the rear of the building and dumped on low land along the old canal.

On the basement floor are located also a gas pump and governor for pumping the sewage gas from the sewage disposal plant into the garbage furnace. The gas pump consists of a Root blower with a Huntoon governor arranged to prevent vacuum on the sewage gas line to such an extent that scum might be drawn into the suction pipe.

The sewage gas will be generated in the new Imhoff tank, and will be burned constantly in the garbage furnace, thus reducing the amount of coal necessary for the incineration of the garbage, and keeping the furnace well heated during the night.

Test openings will be provided in the combustion chamber, the charging furnace, and the flues. A pyrometer and draft-gage will be provided for temperature and draft readings.

The hot-water system consists of a heater and a 300-gallon storage talk, taking heat from the hot gases through coils located in the main flue. The heater is equipped with an auxiliary coal grate. The hot water is to be used for general purposes, such as washing the floors and trucks, and in the toilet-room.

The preheater is that of the Babcock & Wilcox tubular type located in a chamber in the by-pass flue and outside of the main building for convenience. The forced-draft fan is located close to the preheater.

The combustion chamber proper has a volume of at least 430 cubic feet, and is of the down-draft type. Each stoking door is equipped with a dumping dead plate to facilitate the removal, into the ash-pit below, of rough incombustible matter which usually gathers at the doors.

The garbage trucks enter the plant on a slight grade, passing over the coal-bin, through a rolling steel door, 12 feet square, into the garbage charging room. The truck is emptied through the charging opening directly into the furnace.

The building is arranged so that a second furnace may be installed by extending the side walls and connecting the furnace with the chimney. The chimney is sufficient to serve two furnaces each with a capacity of 30 tons a day, and is provided with openings for the flues from the future furnace.

Costs. The bids on the foundations and superstructures of the garbage incinerating plant were as follows:

Item	Description	*Pihl & Miller	Bever & Morris	J. C. Speaker
1	Excavating and grading	$ 1,600	$ 1,795	$ 2,900
3	Concrete work	7,200	8,449	6,500
16	Superstructure	4,560	4,602	7,000
24	Electrical work	250	400	700
26	Plumbing	780	1,570	600
	Total	$14,390	$16,816	$17,700
	Garbage furnace:			
	*Wasteverter Furnaces, Inc.	16,267		
	Total cost of garbage incinerating plant	$30,657		

*Awarded contract.

DISCUSSION

J. F. LABOON: Mr. Keller, the chief draftsman of the firm at the time the first plans were made fifteen years ago, is present. We would be very plad to hear from Mr. Keller.

W. L. KELLER:† That was about the last job I worked on in sanitary engineering. I have forgotten practically all I knew about it, and therefore have no constructive suggestions to offer. I would however like to ask a question. What is the amount of fuel required for the incinerating plant, and what is the heating value of the gas generated in the Imhoff tanks?

J. F. LABOON: The guarantee of the contract was 227 pounds of coal per ton of garbage of specified character.

We find that the Imhoff tanks properly operated will give an average of about one-third of a cubic feet of gas per capita, with a B.t.u. value of 500 to 600. In this particular case not all the gas of the sewage plant will be collected as we have three Imhoff tanks and we are collecting gas from only the new tank. Over half the total sludge will be handled in the new tank, so there will be 2000 to 3000 cubic feet of gas a day, I should judge.

†Koppers Co., Pittsburgh.

P. J. FREEMAN:* Suppose they change the system of collecting garbage and begin to include all the rubbish, will you need to use coal then?

J. F. LABOON: Not necesarily. With a combined system of collecting garbage and permitting the stores to haul material to the garbage incinerator, it would not require fuel. They can even save the boxes for the starting of the furnace and save what little coal they might need in that case. We hope such will be the case but we could not make the garbage bidders believe it because they had been used to the old system of combined garbage and rubbish collection.

P. J. FREEMAN: What is the method of dumping the cans?

J. F. LABOON: They dump them with ashes wherever they can. The ashes and cinders are dumped in the alleys. They tell me the tin cans which are collected make excellent binder material for alley surfaces. In some places they make a specialty of rolling these cans right into the dirt streets. In Greenville they dump them with the rubbish wherever they can.

P. J. FREEMAN: Does the individual pay for removing the garbage?

J. F. LABOON: Yes. Every householder has to have the garbage taken away and this man has a monopoly.

L. P. BLUM:† Is that a fair figure for the cost and conditions of such incineration?

J. F. LABOON: That would be a fairly good average for this sort of design. It is a very substantial design and a safe one. There are no unusual conditions about it. It includes the whole garbage plant complete, roadways, furnaces, and everything ready to operate.

*Chief Engineer, Bureau of Tests and Specifications, Allegheny County, Pittsburgh.
†Blum, Weldin & Co., Pittsburgh.

P. S. WICKERHAM:* I was very much interested in the description of the disposal plant. One statement I can check thoroughly and that is that the sludge from the old plant was of exceptionally good character. Greenville furnished the seeding for the Sharon plant and my recollection is that digestion started without delay.

I was interested in one feature of the design. In the Imhoff tanks you have eliminated the old hoppers and cross walls.

J. F. LABOON: We have a single hopper with sloping sides that permit the sludge to travel unobstructedly to either end of the tank, thus getting optimum results.

P. S. WICKERHAM: I am glad to see that coming into general practice. Our designs incorporated that method some three years ago by way of eliminating individual hoppers. It gives a very much better facility for the interchange of sludge. It also gives a greater effective sludge capacity because you have introduced additional withdrawal pipes wherever these hoppers happen to have been and get more space for active operation, together with simplified construction.

I should also like to ask whether your gas collectors are of the sliding type, or fixed.

J. F. LABOON: They are fixed in this instance. We do not want the trouble New Castle had where the gas shot the domes off.

C. A. KEELAN:† Is there anything that could be done in regard to legislation which would overcome the existing condition of sewage backing up into some cellars after a heavy rainfall? This backing up results in a very bad condition, as I know of an actual case in which the sewage backs up to a depth of approximately two inches over the entire cellar every hard rain storm. Something should be done to remedy this situation.

J. F. LABOON: No. We have legislation to prohibit it, but we do not enforce it. Officials of the state Department of Health pre-

*Consulting Civil Engineer, Butler, Pa.
†Salesman, A. Willis Dalzell Co., Pittsburgh.

sumably have taken the position that they can not enforce it and, therefore, they permitted us to put in relief sewers.

C. N. Haggart:* You have a stack lined the full height. Is that not an unnecessary expense?

J. F. Laboon: In one case (I will not mention the particular job) we found that a crack in the chimney occurred just where the fire-brick stopped. You might say we did not extend the fire-brick high enough in that case, but we had it over half of the chimney. With the Greenville chimney 100 feet high, costing less than $4000, fire-brick inside of it for the additional height to the top would cost only a few hundred dollars more. The temperature strains at the point where the fire-brick leaves off are rather marked; and they are liable to crack a chimney at that very point. The additional cost did not warrant taking the chance.

C. N. Haggart: In designing a heating plant where we used a 150-foot concrete chimney, we provided for a lining for 30 feet. I have not examined the chimney since its erection, but I have never heard any complaint of the concrete disintegrating.

J. F. Laboon: The difference might be accounted for in this way. The ordinary boiler chimney, serving a boiler or a group of boilers, is designed for temperatures of 400 to 500 degrees. If you have any more heat leaving the boiler you are wasting fuel. In a garbage furnace you have a working temperature of 1200 to 1400 degrees and you have to get rid of it. You have probably 1000 degrees in the stack as compared with 500 in the boiler chimney. In the garbage plant, chimney temperatures are much higher than those of steam-boilers.

C. N. Haggart: I want to remark about the concrete in the Imhoff tanks. I think that it is remarkable that the concrete is in such good condition.

*Consulting Structural Engineer, Pittsburgh.

J. F. LABOON: I was very much startled to see it in that condition myself. I can only tell you that we had a good resident engineer on the job; but the contractor lost money, we know that.

P. J. FREEMAN: Did you use slag or stone in these beds?

J. F. LABOON: Neither, as no filler was required.

V. R. COVELL:* I have been very much interested in the paper, but my experience has been too limited to enable me to contribute anything constructive to the discussion. I chose sewage disposal for my thesis at the university, but it was 15 years before I became directly interested in the design of a plant.

In compliance with a demand that the sewage from the Allegheny County Home at Woodville be purified before it was discharged into Chartiers Creek, I designed a disposal plant, which was approved but subsequently it was agreed that the construction be postponed and consequently the plant was not built. I was impressed at the time with the fact that so many new terms and processes had been adopted that little, which was current practice 15 years before, could be used. During the nearly twenty years which have since elapsed, the changes have been fully as great, and I can not now qualify as a sewage disposal engineer. It seems that as great progress has been made in this branch of engineering as any other in this third of a century.

*Chief Engineer, Bureau of Bridges of the Department of Public Works, Allegheny County, Pittsburgh.

HAND LOADING WITH THE BLOCK SYSTEM IN CONCENTRATED MINING*

By M. D. Cooper†

To discuss hand loading at this time seems somewhat out of place when attention is quite generally turned away from that class of work and directed strongly toward mechanical loading. However, for the reason that this discussion, as a whole, is planned to include a broad survey of mining conditions, hand loading may be considered as an essential part, in spite of its decreasing importance. A recent report of the United States Bureau of Mines shows that the hand pick is not yet obsolete, as 14.2 per cent. of all bituminous coal produced in the United States in 1928 was mined by hand. In Maryland, 71 per cent. of the coal is hand mined; in Pennsylvania, 28.7 per cent.; and in West Virginia, 13 per cent. Moreover, hand loading still plays an important part even when the coal is cut by machine, cutting having progressed steadily from half of all coal mined in the United States in 1913 to three-quarters in 1928. In any case, hand mining has the same priority as all other hand methods in industry; it has served as the model from which other methods have grown, and illustrates the truth of the Latin proverb, *Facile est inventis addere*—it is easy to add to what is already invented.

In spite of all its shortcomings, hand loading still has one advantage over machine loading; that is, in the matter of clean coal. With proper discipline, it is possible to have the miners clean the coal as it is loaded by hand. Loading machines may be highly efficient mechanically; but, so far, they have not been developed to such an extent that they will take out impurities. In fact, it seems probable that machines that are set at work to load large tonnages will require adequate cleaning plants on the outside, the cost of which may offset the economies gained by larger output.

Hand mining is generally limited to such tools as the shovel, pick, bar, wedge, drill, and explosives. Even in modern mechanical methods the same tools are employed, but not to the same extent.

The block system is the outgrowth of the "panel" and "room-and-pillar" systems; in fact, it may be considered as one form of the

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†Division General Superintendent, Hillman Coal & Coke Co., Pittsburgh.

panel system in which the rooms are so developed that the coal area is separated into rectangles, or more desirably, into squares. The ideal block system is probably the one in which entries and rooms are driven 100 feet from center to center, although successful operations have been carried on with both longer and shorter distances. In general, entries and rooms are driven from 10 to 12 feet in width.

The essential requirements of the system, in addition to division of the field into rectangular blocks, are engineers' sights for all places to be driven, full retreat operation, and regularity of procedure in drawing ribs. It is evident that blocks of regular size can be developed only with constant sighting, and regularity is a necessary part of the system. As in most practical methods of mining, full retreat is essential. Entries are driven to the end line of the panel to be mined or the boundary of the property, as the case may be, and at the end, rooms are driven at right angles and only from one side of the butt entries. These rooms are driven in regular order, the most inby being started first, the next room outby after the first has advanced a predetermined distance, and so on. Timing is so arranged that the advancement of the rooms and break throughs is maintained at a regular schedule. Then when the retreat work begins each block is marked for extraction in such order that the fracture line may be almost straight and may move parallel to a predetermined direction. In that manner the weight of overlying strata is evenly distributed over the blocks along the fracture line, thereby avoiding excessive weight on any one block, with its consequent difficulties such as crushing of coal and heaving of bottom.

From 75 to 80 per cent. of the coal is mined on retreat; and, therefore, relatively slow development caused by wide centers is outweighed by concentrated retreat under favorable conditions. Because several men may be worked on the block that is to be removed, the output is larger, and supervision may be greatly increased.

In following the leadership of the H. C. Frick Coke Company, the system was brought into use in the Connellsville coke region, where it continued as the principal method, but is now being replaced by other methods to be described later. In 1910, discussion in the Brownsville Mining Institute led to the introduction of the block system of concentrated mining at Bridgeport mine, then under the

supervision of W. C. Hood. P. J. Mullin, inspector of the H. C. Frick Coke Company, and W. H. Howarth, inspector of the Sixteenth Bituminous District of Pennsylvania, aided the introduction of the system. Soon it spread to other mines of the Company, and then to the mines operated by other companies.

On account of the narrow width of entries and rooms, roof support is generally good. Moreover, the usual practice is to leave several inches of coal on the roof to avoid the slaking effect of moisture carried in the air on the slate or rock above. Regularity of size of blocks permits an even distribution of weight of cover. The result is that safety is promoted both in the driving of the places and in extraction of the blocks during retreat. Especially is it advantageous in retreat work to have solid support of large rectangular blocks rather than small uneven ribs. In this connection, attention may be called to the advantages that are readily apparent in the development stages of a mine when diagonal entries seem to offer opportunities for shortening haulage routes. However, they cause the formation of irregular blocks of coal that contrast sharply with those developed in the block system, and the irregular blocks are generally extracted years later with difficulty and danger.

Ventilation of working places in the concentrated system of mining may be made very satisfactory. Since no places are turned before they are required, there are no standing places to fall in and accumulate gas. The air current may be conducted along the edge of the gob area and directly to the return air course.

It must be admitted that the block system has some disadvantages. In opening a mine, on account of the great distance between centers that is a necessary part of the system, rooms can not be turned as rapidly as in the usual room-and-pillar system. Where blocks are large and centers well over 100 feet apart, the working faces may go too far ahead of the air by the time an entry is driven the length of a block and a break through cut across from one heading or room to the other. As a source of lump coal, the system is not as satisfactory as some others, on account of the fact that all places, rooms, and entries, are driven narrow. However, in the Connellsville coke region, where the system has been most used, the size of the coal was not important as large lumps are not desirable in charging coke-ovens.

Costs of labor and material are expected to be somewhat higher in development work on account of the smaller number of working places made available per acre. On retreat, however, costs should generally be less under normal conditions. On account of the strength of large pillars, costs of retimbering and grading should be kept at a minimum. One feature of hand loading by the block system, that is favorable to the cost of mining, is the fact that the loader is required to clean up the cut each day, cutting being done at night. As a result of this practice, miners are loading from 12 to 20 tons a day, according to the width of the places and the thickness of coal.

Accidents are not directly caused by this system; that is, the records show that the usual averages of accidents from cars and locomotives, falls of roof, handling of explosives, etc., apply to the system and that there are few, if any, that can be charged to the system itself.

This system of mining has produced a high recovery per acre. Properly carried out, it eliminates the danger of squeezes. It gives the miner the opportunity to load a large daily tonnage, as nearly all of the coal may be undercut, and only a small percentage is pick mined.

It is likely that hand loading will gradually disappear as loading machines become more highly developed and generally used. However, for years hand mining will continue in those mines well developed at this time and therefore not easily converted to systems of mechanical loading; in such mines the advantages of the block system may be applied, at least in part.

CONCENTRATION IN MINING ABROAD*

By Howard N. Eavenson†

Your Chairman has asked me to talk to you to-day about what is being done in concentration in mining abroad. The only foreign mines with which I am personally familiar are those in Germany, and to some slight extent some of the English mines, and I will confine my remarks to-day mainly to the German mines and especially to those in the Ruhr district.

Concentration in mining in its broad sense refers, of course, not only to concentration inside but to concentration of plants and of surface equipment. The mining conditions abroad are so very different from those in most of the bituminous mines in this country that it is quite difficult to make a fair comparison.

Practically all of the German mines, excepting those in Silesia, are working seams that are very highly inclined, the pitch ranging from 15 to 70 degrees, and, of course, methods that are suitable to our flat seams would not work so well under these conditions. The illustrations show methods of working in the Ruhr much better than they can be described. Fig. 1 and 2 are from R. A. S. Redmayne's "Modern Practice in Mining," v. 3, 1914, p. 29. Fig. 3 is from *Colliery Guardian,* June 22, 1928, p. 2443. Fig. 1 shows a section of the Gelsenkirchen colliery, in which the seams are pitching at an angle of about 45 degrees. The main shaft is sunk through the various seams, and at intervals of about 100 to 150 meters each, depending somewhat upon the pitch of the seam and upon the company, main levels are run from the shafts. These are haulage roads that are driven through the rock and across the various seams, and permanently protected. At various places along these main drifts auxiliary shafts are sunk to depths of from 30 to 45 meters, depending upon the slope of the seam, and from these small shafts, gangways or haulage headings are driven along the seam. These haulage headings are spaced so that the distance between them on the seam is approximately 100 to 120 meters, or from 328 to 400 feet, and headings are driven partly in coal and partly in rock, large enough to give clearance for the mine-cars.

*Presented November 26, 1929. Received for publication March 17, 1930.
†Howard N. Eavenson & Associates, Pittsburgh.

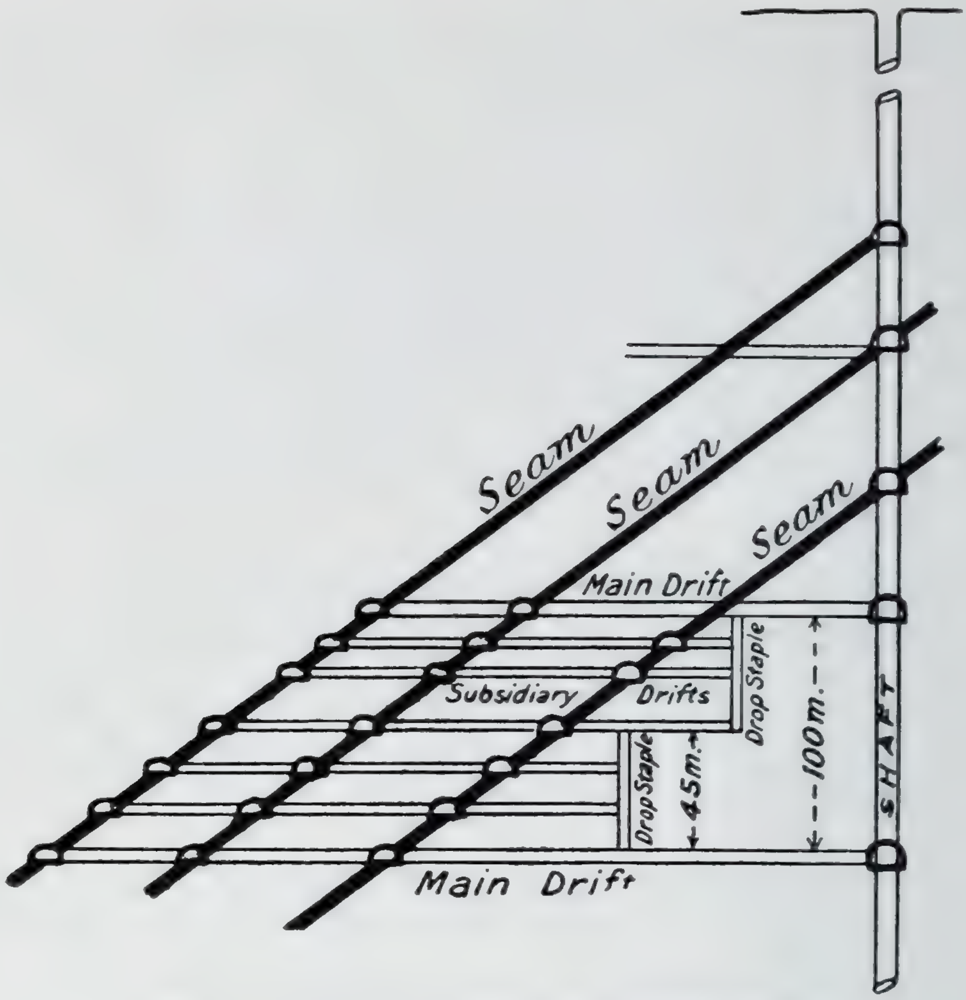

Fig. 1. Section at Gelsenkirchen Colliery.

After a barrier pillar is left at the shaft, a heading is driven straight up the pitch to the haulage-way above, and from this the long face or long-wall working is driven parallel to the strike, taking out all of the coal between the two headings, the heading itself being protected by cribwork and by heavy timbering, and sometimes by pack walls. This arrangement is shown in Fig. 2.

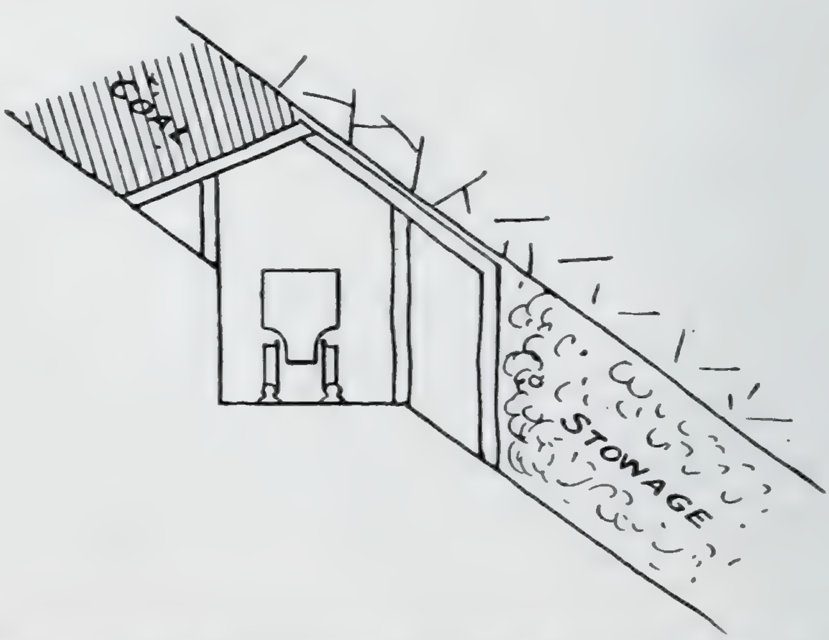

Fig. 2. Section of Subsidiary Drift at Gelsenkirchen Colliery.

Where the pitch is no greater than 30 degrees, conveyors are used to transport the coal from the face to the loading point, most of these being of the reciprocating type, although other types are also used. The coal is taken from the face by the hewer, who is the skilled man, and who uses a small compressed-air pick somewhat like a jack-hammer drill. In all of the gas coal seams in Germany shooting is forbidden in the coal itself, and all of the coal is recovered in this way. The shovelers load the coal into the conveyor, and it is drawn off into the mine-cars—which are usually of about 1500 to 1600 pounds capacity—along the heading, and these are transported by hand or motor to the auxiliary shafts, hoisted or dropped from them to the next level, and then taken to the main shaft, where they are hoisted to the tipple.

Where the pitch of the seams is greater than 30 degrees, the coal slides in chutes or on steel plates, and where the pitch is steep enough it is allowed to run on the floor. In some places I saw they used small auxiliary hoists, on the platform of which the hewer can stand in order to work along the coal face, and in some places batteries were built so that two or three hewers could work along one face, allowing the coal to slide along the bottom so that it could not interfere with the men working below. In this case, of course, the face is broken rather than kept in one long straight line. This method of working is universal throughout the Ruhr district, and it is difficult to see how it could be much more concentrated than it is.

Advance of the face is not as rapid as it would be under our conditions, because the mining laws in Germany require the back-filling of all working places as the coal is mined out, and the main problem that they have is to carry the backfilling along as rapidly as the face advances. In fact, I was told by the management of every mine that I visited that their problem was not to get out the coal, but to keep the stowing near enough to it to comply with the requirements of the law.

The timbering in all of these places is very systematic, and the timbers are set very close together, although they are much smaller than we are accustomed to use. Along these timbers a line of chicken wire of about one-inch mesh is placed about six or eight feet from the face, and the filling material is placed between the last section and this wire. In the flatter seams the filling is put in by hand

or by conveyors or machines, but in the steeper seams it is placed from cars from the haulage heading above, this arrangement being shown in Fig. 3. The material used is rock from the mines, or ashes, or

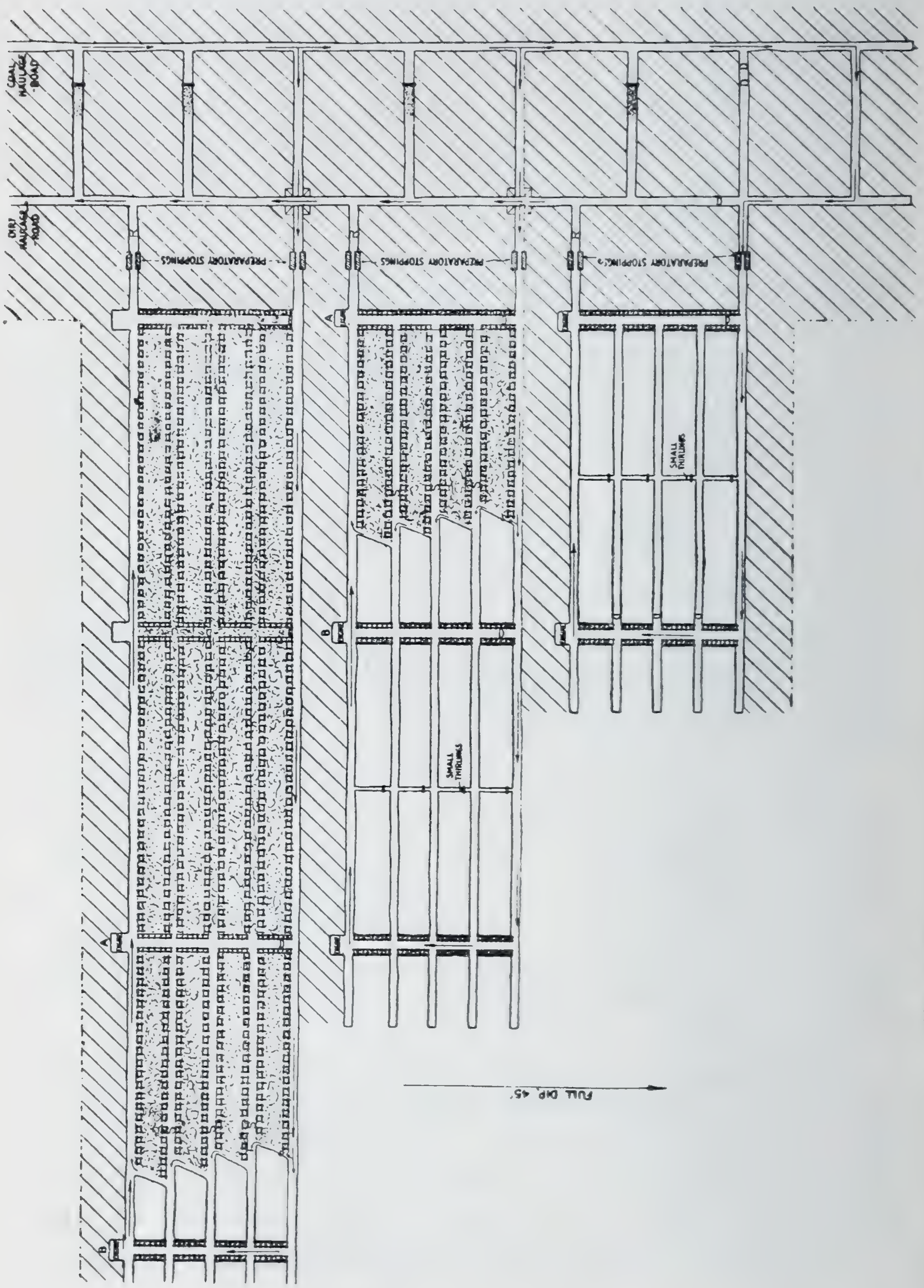

Fig. 3. Heading and Drifting Methods, Advancing along Line of Strike.

refuse that was originally taken from the mines and wasted outside; and it requires a very great deal of work to handle all of this material and to keep it placed properly. The nearest estimate I could get on this was that it took perhaps 25 per cent. of all the labor in mining to do this stowing. It is not difficult to see that the advance or production of coal could be very much expedited if it were not for the necessity of stowing behind, as I believe in most places the control of the roof would be sufficient to enable the workings to move rapidly without serious trouble.

Since 1923, when the mark was stabilized and Germany began to "come back," the progress in concentration of plants and in mechanization of mines has been very marked. The use of machinery of all kinds is increasing rapidly, although, of course, we must keep in mind in comparing their work with ours that labor in Germany is very much cheaper than it is with us, and this of course reduces the amount of machinery they could otherwise economically use. An example of what has been done inside the mines is given in the following figures, which were taken from an article published in *Glückauf*.* They show what was done at a representative pit between January 1926 and August 1927.

	January, 1926	August, 1927
Length of long-wall and stall-working faces	5,500 feet	400 feet
Length of conveyor faces	5,690 feet	8,170 feet
Total length of working faces	11,190 feet	8,570 feet
Number of conveyors	25	29
Monthly output from conveyors	28,149 tons	63,173 tons
Amount conveyed by conveyors	38 per cent.	73 per cent.
Amount conveyed per meter of conveyor face	0.66 tons an hour	0.92 tons an hour
Average amount conveyed per conveyor	47 tons a day	81 tons a day

This statement, I think, is typical of the progress that is being made in all mines, as practically all of those that are now running have undergone a similar change within the last five or six years.

The output per shift at the mines that I saw was from 80 to 100 tons per place. As stated above, this was limited by the time required for backfilling.

In the group of mines that I inspected, in 1924 the hewers and loaders produced 1.76 net tons per man per shift. In 1928 they were

*V. 64, p. 696; abstract *Colliery Guardian*, v. 137, p. 142.

producing 2.37 net tons per man per shift, which was considerably better than the average of the Ruhr district. This was for the actual workers at the face. For all underground workmen the tonnage increased in the same time from 1.14 to 1.59 net tons per man per shift, and for all workers of all places from 0.89 net tons in 1924 to 1.29 net tons in June 1928. One of the shafts in this group held the record in the Ruhr for production per man per shift of 1.56 net tons, which includes all labor both above and below ground. These figures compare with English figures of about one ton per man per shift. In a recent book entitled "The Recovery of Germany" by Professor James W. Angell (published for the Council on Foreign Relations, by Yale University Press, 1929), the statement is made that from four to five times as much machinery is now being used in the mines in the Ruhr as was used in 1913, and in 1927 over 85 per cent. of all coal being produced in the Ruhr was produced by machinery.

In addition to the concentration and mechanization of the underground workings in the German mines, there has been a process of what is called there "rationalization" of mines during the period since the stabilization of the mark. This so-called rationalization is really a system of rebuilding or concentration of the mines, so that a large number of plants is being concentrated into a smaller number, the number of tipples is being reduced and the output per tipple increased. The coke plants are being rebuilt along more modern lines, new washers being installed, and in general there is a complete rebuilding of the plants along more economical lines. Our old friend, Mr. E. N. Zern, in *Coal Age* ten years ago made the statement that "while machinery has utility, it produces revenue only while it is at work," and this fact is not appreciated in our coal mines in this country nearly as much as it is abroad. For instance, it is a very unusual thing in the United States to find a bituminous mine working two shifts, and when the statement is ordinarily made that a mine is double shifting it means only that a certain percentage of the headings is being driven and some coal is being hauled, but that none of the rest of the plant is working. In Europe practically all of the mines work two complete shifts a day, so that the machinery is working at least two-thirds of the time instead of only one-third as it is here. The gains made by this are very substantial, particularly when the amount of equipment installed per ton of capacity is so great.

In the group of mines that I inspected, the properties had originally been developed by 22 plants. By various consolidations these had been reduced to 15 operating plants last year, and by the end of this year this number will be further reduced to 10 plants, which will have the same capacity as the original 22 and the same participation in the sales syndicate. That this movement is not confined to any one company is shown by a report of the German organization which corresponds to our United States Steel Corporation, for the year 1928, in which it is stated that in coal-mining the number of shafts in operation has been reduced from 48 to 34, and the production maintained at the same level. Since the formation of this company, about four years ago, more than 80,000,000 marks, or $20,000,000, has been expended on coal washing, coke-ovens and by-product recovery plants, and other large amounts on the concentration of the various shafts. Dr. Angell says in the book previously mentioned that the total number of mines in Germany has been reduced from 384 in 1923 to 303 in 1927, which is only slightly more than the number in operation in 1913 and a decrease of 21 per cent. since 1923, while during that time the output has been steadily increasing.

In England the same process of concentration is going on, but not to such a great extent as in Germany, this being partly due to the greater conservatism of the English operators, and partly due to the great amount of trouble they have had with labor since the World War. The report of the Royal Commission on the Coal Industry in 1925 makes the following statement about utilizing the mine equipment to the greatest possible extent:

> "It appears to us reasonable that no obstruction should be placed in the way of the fullest possible use of the mine by the employment of double shifts of men. In general, the economics made possible by it are very substantial. A larger quantity of coal is obtained on a given day from each face and along each road. The quicker advance of the face generally makes for better roof conditions and so for safety, as well as allowing a saving in timber."

In the most modern English plants, however, hoisting is now being done in two shifts and the output per mine is being increased very largely, and last summer I visited a mine where the output had been increased to 6000 tons a day, this being obtained from two shafts working two shifts each; and very great changes are being made in the English plants on account of the necessity of better preparation.

In 1927, however, there were in use in England 1787 conveyors of various types, while in the Ruhr district alone in mines producing about 60 per cent. of the German output there were 7660, which shows that the mechanization process in England has not reached the extent that it has in Germany.

DISCUSSION

J. R. CAMPBELL:* It might be of interest to point out the character of the coal in pick mining in the Ruhr, as compared with the American coals. You spoke of gas coal and coking coal, high-volatile and low-volatile coals.

H. N. EAVENSON: They have all kinds of coals. I think the largest number of seams in any district is 34. The lower seams are low-volatile coal corresponding in volatile nearly to our anthracite—seven to eight per cent. The next higher seams have from 15 to 18 per cent. volatile matter, something like our smokeless coals of West Virginia and Central Pennsylvania. Above that they get into the coking coal and the gas coals, and above that what they call a gas flame coal, which would be something like our long-flame, high-volatile coals from some parts of Kentucky and West Virginia. The volatile matter in these runs as high as 38 per cent. In what they consider their best coking coals it ranges from 22 to 28 per cent.; in gas coal from 28 to 34 per cent., and in others from 34 to 40 per cent. Some of the mines produce some of each kind of coal. Some of the newer mines are only in the upper seams as yet.

L. E. YOUNG:† In the mine you referred to, was the objective more than one cut in 24 hours?

H. N. EAVENSON: Those places were laid out to get one cut per shift. I think that is limited entirely by the fact that it takes a great deal longer to backfill than it does to load the coal. They could do a great deal more if they did not have to do the backfilling. That is the limiting feature in Germany.

*Bituminous Representative, Koppers Rhéolaveur Co., Scottdale, Pa.
†Vice-President, Pittsburgh Coal Co., Pittsburgh.

L. E. Young: Do you have any figures indicating the cost of product loaded at the railroad car in Germany?

H. N. Eavenson: Yes, but I do not believe I have them with me. I think as a usual proposition their labor cost now is running from \$1.65 to \$1.85 and total cost \$3.50 to \$3.75. They vary a great deal in different places and in some mines may be a great deal higher than that. Their material cost is very high, about 70 cents a ton, something like that in the anthracite region.

L. E. Young: What are the regulations in regard to back-filling with respect to the material used and the compactness with which it is to be applied in the openings?

H. N. Eavenson: As far as I was able to find out (I did not have very much time for it) the only place they specify hydraulic packing is where they are mining under public buildings or under steel-works. They do take the coal from beneath steel plants in Essen, and, with hydraulic filling, the settlement is very much less. They get as a rule less than 10 per cent. subsidence with that type of work. They can take the coal out from under large areas without interfering with the operations above. In the other work, where they are using ordinary filling, they expect a subsidence of anywhere from 15 to 20 per cent. I think the only requirement is that it must not be of inflammable materials. The main requirement is to protect buildings or machinery in plants above.

J. R. Campbell: What is the thickness of the seams?

H. N. Eavenson: Anywhere from 30 inches up. They told me that they had seams eight and nine feet thick, but I think the average is about 4½ feet.

SCRAPER LOADERS IN DEVELOPMENT WORK*

By T. F. McCarthy†

The term "scraper loader" is derived from the combination of a rope hoist and a scoop that is hauled over the bottom between the face and the loading points. Two general types of hoists are in use:

1. The stationary type, which is located remote from the loading chute.

2. The self-contained type, which is an integral part of the loading chute.

Each type has either two or three drums. One of the most flexible of the self-contained type is the three-drum self-propelling unit similar to the Goodman entry loader. There are numerous designs of scoops in use and the type most generally used is the rigid or semi-rigid, open-bottom scoop, although there are a number of automatic loading and unloading designs that have proved very successful and are coming into more general use.

Our use of scraper loaders in development work was brought about by the need of more rapid development. In our low coal, ranging in height from 32 to 44 inches, large development areas are required for comparatively small tonnages and rapid speed of development is necessary to get a proper degree of concentration in our work. In our field we encounter frequent rolls and troubled areas, abrupt changes in grades, and considerable water in dip workings. These conditions make it difficult to get hand loaders for this work, particularly on a double-shift basis.

We have used the Goodman entry loader exclusively in this work. We favored this type of equipment because of its portability and relative simplicity; also due to the fact that, being a track machine, when it is moved to a location work can be started immediately.

The entry is driven ten feet wide for a distance of from 200 to 250 feet in the coal. As the entry is advanced, the room necks are made by loading out one cut and undercutting the second cut. If it is to be driven wide, slabbing cuts are taken to bring it to the required width. The machine is then located in the cross-cut, and

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†Assistant General Superintendent, Clearfield Bituminous Coal Corporation, Indiana, Pa.

the parallel entry, or air course, is driven up. In driving this parallel entry a third rope is necessary to guide the scoop around the turn. If it were not used an open sheave would be required, which would necessitate an additional man at this point.

The coal is undercut with a standard, or low-vein, mining machine and drilling is done with an electric drill. After the coal is taken out, the roof or bottom is brushed, using a rock loader or scraper loader, or it is brushed by hand.

Unless unusual conditions are encountered, this work is done on a contract basis. Our experience has shown that an ordinary three-man crew under average conditions will load out three of the six-foot cuts per shift. Under good conditions a well organized crew can load out four or more cuts a day.

Time studies made for three successive days on a crew that averaged three cuts a day, show that only about 30 to 40 per cent. of the time is required in loading out the cut. The rest of the time is about equally divided between cutting, which includes moving the machine to and from the face and changing the bits; and in shooting, which includes drilling, tamping, and waiting for the smoke to clear out. As a part of the regular duties of the crews they must set all timber except break row, when the entry is driven wide; also take care of extension of ventilation tubing, and make the necessary pipeline extension where water is encountered.

We have experimented with many devices to facilitate the loading out of the coal, among them being pans under the cut, and self-loading scoops, but the reduction in time in the loading out operation was so small for the complete cycle that the crews did not want to be bothered with them. The time studies do show that, as the greater part of the cycle is required in the cutting and shooting operations, our real need is a continuous cutting and loading machine. To my knowledge no machine of this type has been developed for our peculiar conditions.

One of our greatest difficulties has been to develop competent crews, as it requires men having considerable mechanical ability to get the best results. This is characteristic of our problems in all forms of mechanical loading, and it shows that we must train our men mechanically to get the best results in this work.

THREE-SHIFT OR CONTINUOUS MINING*

By H. E. Mason†

Introduction. This meeting having been called for the general discussion of concentrated mining in Pennsylvania, your very efficient committee on arrangement, having learned that the Trotter mine of the H. C. Frick Coke Company had been operating more than one shift a day, for some years, sent us an invitation to read a paper at this meeting, on the general practice and the experiences met with in this method of operation.

Having had several years of experience with this method of operation, the honor of preparing and presenting this paper was conferred on me. I have given the matter my best efforts and hope that you will find the following interesting and instructive.

Mines Working More Than One Shift. Of the mines operated by the H. C. Frick Coke Company in the coke region, we have about 15 that operate more than one shift. Six mines have recently been working on the three-shift basis, four have been working two shifts, and the remainder have been working more or less two and three shifts as the case may have demanded in certain bad sections of mines.

Thinking that perhaps you will be more interested in hearing of the three-shift or continuous method of operation, and since this method is not so commonly practised, I shall dwell particularly on that arrangement.

Meaning of the Three-Shift or Continuous Operation. Three-shift or continuous operation means that the section or mine, whichever the case may be, operates each and every working place continuously 24 hours a day. In most cases it operates six days a week, Sundays being idle. The days are divided into three eight-hour shifts.

The time for starting shifts varies at different mines, for local reasons such as street-car accommodations. The general practice is that the day shift starts at 7:00 A. M. and ends at 3:00 P. M., the afternoon shift extends from 3:00 to 11:00 P. M., and the night shift from 11:00 P. M. to 7:00 A. M. All shifts start and end at the working place.

*Presented November 26, 1929. Received for publication February 17, 1930.
†Superintendent, H. C. Frick Coke Co., Bridgeport Mine, South Brownsville, Pa.

Origin of Plan. The three-shift method of operation did not originate with the H. C. Frick Coke Company. I believe it was in 1921 that we first got the idea of its workings, when we learned that the Cambria Steel Company was operating in this manner in its Rolling Mill mine at Johnstown, Pa. This was just preceding the 1922 labor disturbance and, of course, opportunity was lacking for a try out at that time, but in 1923 it was introduced in our Trotter mine, where we first started with two shifts and shortly thereafter followed with the three-shift arrangement. It seemed to give the desired results, and was taken with such good grace by the men that other mines have since been included in this arrangement.

The Trotter mine, like many others in the coke region, was designed and equipped for supplying the charge for a definite number of ovens each day. The possibility that it might some day be a coal production plant only was not considered. Some of its equipment is therefore, somewhat obsolete for its present operation, and this accounts for a certain amount of inefficiency in the operation. It is a shaft mine, with surface cover varying from 250 to 600 feet, and nine feet of coal overlaid with draw slate and underlaid with limestone. It is a very old mine that was about thirty per cent. worked out when acquired by the Company. The original owners had extracted most of the coal within three-quarters of a mile from the shaft bottom. This left only five narrow necks of coal ranging in width any place from 400 to 800 feet as a support for haulage, air course, manway and drainage headings connecting with the outlying coal area of the mine. These headings had many cross-cuts and side entries, and every possible place was packed full of slate. The headings were very wide, having weathered for years. The excessive width demanded frequent and substantial retimbering. Approximately 10 per cent. of the coal was mined out of these necks. The full surface settlement was resting on the coal between the gobs. The floor of this mine is rolling and full of swamps, lying adjacent to the Youghiogheny River, and it was necessary to pump to the surface about 3,500,000 gallons every 24 hours. The output per single shift was falling down, costs were mounting, the existing coal area was not sufficient in size for economical mining lay-out, or introduction of modern mechanical mining equipment for the speedy recovery of the coal. Everything indicated that it was going to be a long drawn out

and expensive operation by single shift. These matters considered, any scheme for the quick disposal of this mine was welcomed. There were plenty of willing men in the region. Thus came about the introduction of the three-shift idea.

It has been said "we can't stretch a single hour but we can intensify its output," and again it has been said that "seconds saved are dollars earned." These little maxims somehow seem to fit in with this three-shift idea.

Organization for Three-Shift Operation. There is a mine foreman in full charge of the whole operation, and he alternates his visits in the mines so that he can keep himself acquainted with the conduct and working of each shift. There is an assistant mine foreman on each of the sections for each shift, and he will have from 15 to 25 working places with two miners working in every place; also the necessary number of drivers, shot firers, timbermen, roadmen, and laborers to accommodate his working places and conditions. The shifts rotate every two weeks, including assistant foreman and men. The assistant mine foreman also performs the duties of fire-boss. He goes in the mine about two hours in advance of his men and makes the fire-boss run or inspection. He then makes about two rounds of inspection as assistant and his last round again as a fire-boss, so that he can sign the record books before the entrance of the next shift. He signs the books both as assistant foreman and as fire-boss, and instructs the ingoing shift with regard to their places of work and conditions. Mining all by pick work, miners generally practice the over mining of coal and the bottoms are shot up. It takes about two hours in the preparation of the over mining, which is about four or four and a half feet deep, places being driven about eleven feet wide. This produces about nine tons per miner per shift, or 54 tons of coal per 24 hours per place, the place advancing about thirteen feet in the same period of time.

The miners do their own timbering. The maximum distance of timbering is four feet or less, depending upon conditions, center post and stub post being used at the face. As nearly as possible, we work the face by the room-and-pillar method, or what might be called the modified short-wall system. Miners lay their own track in their working places. Shot firers are likewise combination men. In the lapse of an hour and a half to two hours in the beginning of a

shift, while the miners are doing their overmining, the shotfirers do timbering, laying of track, etc. It is usually necessary to have two shot firers on each section to expedite shooting since all the miners are ready to start at about the same time. An average of two holes is shot in each place per shift.

The shot firer sells powder to the miners before they go into the mine and buys back the surplus outside the mine at the end of the shift. The live stock is delivered to and taken away from the driver at the sectional landing. All men stay in their working places until relieved by the incoming shift. You will note that the time spent underground by this three-shift arrangement can not possibly exceed eight hours, plus the traveling time to and from the working places. I do not know that we have a mine working under this arrangement where the time is greater than nine hours from outside to outside.

Results of Three-Shift Operation. It is expected that we will finish the mine in about one-third the time it would take on the single-shift basis. Costs of pumping, drainage, and ventilation as you know, go on 24 hours a day and the equipment therefore has to be kept in proper operating condition whether the mine is operated one shift or three, thus we will have two-thirds saving from this source. Production is the same on each shift and exceeds that if only one shift were worked, since there is no lost time or effort in preparing places to stand over night.

Places are driven over and retreated generally before the full effect of subsidence has taken place. More coal is produced per life of mine-cars, rail, rope and ties. Inventory, insurance, taxes, and general overhead are all reduced by the shortened life of the mine. We have one mine where they have sufficient mine-cars to mine all three shifts but hoist only two shifts, thus saving hoisting and haulage crews for the one shift. Considering the conditions that the management has to meet in these three-shift mines—extra slate cleaning, less than capacity use of transportation equipment, small necks of coal territory which are insufficient for an economical lay-out, and high supervision costs on the small sections—the costs run only about 15 to 20 per cent. higher in the three-shift mine than in some of our one-shift mines which are most modern in lay-out and mechanical equipment. We feel that, everything considered, we are saving from

30 to 40 per cent. by operating these old mines on the three-shift arrangement, as compared with the same mines on the one-shift arrangement.

The mechanical force, in the shops on the outside work only one shift.

Accidents. The 1928 record of accidents for the H. C. Frick Coke Company indicates that the mines working on the three-shift arrangement were very much better than mines working otherwise, two of the mines in particular (Trotter and Lemont) having led the Company for the least number of accidents. Trotter mine, with an average of 337 men a day, had no disabling accidents during all of 1928 and for the preceding five months in 1927, making a total of seventeen months without a disabling accident. Lemont mine, with an average of 633 men a day, had 11 disabling accidents, or an accident rate of 1.74 per 100 men employed. Looking at this matter from the tonnage standpoint, the six three-shift mines produced 2,781,702 tons of coal in 1928 without a fatal accident, 154,539 tons per serious accident, and 103,026 tons per miner lost-time accident.

The accident rate for the whole H. C. Frick Coke Company in 1928 was 1,251,000 tons per fatal accident, 75,000 tons per serious accident, and 42,000 per miner lost-time accident, with an average accident rate of 5.76.

The favorable accident rate in the three-shift mines might be attributed to smaller sections being worked with greater supervision; to closer contact and better schooling of the men; and to the men being trained to stay in their working places until the incoming shift arrives to observe men and workmanship. This, we believe, has some moral effect, inducing the miner to keep his place in better shape, which means, to a great extent, safer shape. Of course we can not imply that a three-shift operation will guarantee a reduction of accidents any more than we can say that we no longer have to contend with the human element.

Attitude of Men. I feel certain that the first question that will come into your mind regarding this manner of operation will be that of the satisfaction of the men working on the changing shifts. As I stated above, the day shift rotates to the afternoon shift after a stay of two weeks on the day shift, and so on to the night shift. This

latter shift, of course, is the most unsatisfactory to the men, due to the difficulty of sleeping and getting their rest in the daytime. Especially is this true during the summer months because of the heat and also the disturbance by the children who are out of school at that time and usually playing and making noise around the house. The men claim that it takes about two days' time to become accustomed to sleeping through the day. This complaint no doubt is justified, but somewhat offset by the fact that on each change of shift they do some complaining for the first day or two, but after that their dispositions are quite cordial. It seems to be the natural disposition for miners to complain at the least provocation anyway. I think the real fact of the matter is that they greet the changing shift somewhat expectantly. There seems to be just enough whirling around to keep the job interesting, or a little on the order that "a change of work is as good as a vacation." We have never had any trouble with the men on this score. I do not recall that we have ever had a man quit work due to the changing shifts. At Lemont mine we average less than a five per cent. turnover in employees.

The hardest work in a three-shift operation is most assuredly done by the mine foreman, who has to keep mighty close watch of details and conditions. He must keep planning ahead and co-ordinating the work, and forever fostering co-operation among his foremen and men.

DISCUSSION

M. D. Cooper:* What is the actual process of changing shifts?

H. E. Mason: We usually start that change on Monday morning.

M. D. Cooper: I mean from the three o'clock shift to the eleven o'clock shift for instance.

L. O. Lougee:† If any of these men fail to clean up their places in their shift, how is that adjusted with the incoming man?

*Division General Superintendent, Hillman Coal & Coke Co., Pittsburgh.
†Civil and Mining Engineer, George S. Baton & Co., Pittsburgh.

H. E. MASON: We find that the men generally know just about how much coal they can get down before their quitting time. There is no friction on that point at all.

L. O. LOUGEE: Are these men paid on a tonnage basis just like the others?

H. E. MASON: We pay them by the wagon.

M. D. COOPER: It would be interesting to know how you keep the tools from being stolen.

H. E. MASON: Having three shifts of men there, every man owns his own tools, consisting of picks, shovel, axe, saw, slate bar, wedge, sledge hammer and auger, supplemented by safety-toed shoes and glass goggles. We have insisted on this individual ownership for several reasons:

1. All the tools are locked up by the miner in a special tool locking device. This keeps the tools together.

2. If every man is compelled to have a full set of tools, a frequent check by the foreman being made to see that this is in effect, the reason for stealing is greatly lessened.

3. Changing conditions at times makes it necessary to change men about and if they all have their own tools there is never any chance that two men will be put together without a full set of tools.

SCRAPER LOADING ON WIDE FACES

By Fred Norman†

The Allegheny River Mining Company has for some four years tried out different methods in scraping coal from face to mine-car, and has been quite successful in the undertaking. The main thing in view is of course to cheapen production, and to this end several tests with mechanical loaders were made, with the result that, under the existing local conditions, scrapers were found better adapted for the purpose than other types of mechanical loaders.

After some more or less fruitful attempts, feeling the way as to equipment and mining methods, success was finally achieved in organizing the scraping of coal on a fairly systematic basis.

The first endeavors were along lines of the V system, as developed at Norton, W. Va., and this sytem is giving satisfactory results under certain mining conditions. From this were developed other methods, to meet the varying conditions encountered—modifications of the V system, the panel system, and a combination of the two. Of these, the panel system, where the roof permits the operation, appears to be the most economical. The combination has also proved efficient and better adapted to roof conditions than the straight panel.

To scrape coal successfully, certain mining conditions are essential. The roof must be easily controlled, and the floor firm, but plastic enough to give a smooth slippery surface, after two or three passages of the scraper, or scoop. A hard firm clay seems to lend itself well to scraping.

The V faces are on different angles and lengths, governed by roof conditions. The scraper or scoop travels in a center road or gateway between two opposite faces which are worked alternately, or the scoop is operated on one face only from each gateway. This system is also in use drawing entry stumps, utilizing one of the entries as the gateway, and angling the faces across the pillars.

In the panel system, a block of coal about 200 feet square is bodily drawn on the retreating method. Gateways are driven on opposite sides of the block, at right angles to the gathering entry. The hoist and the empty cars are placed in either gateway. The scoop

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†Chief Engineer, Allegheny River Mining Co., Kittanning, Pa.

is operated across the entire face of the block, scraping the coal to the cars in the gateway. The hoist is placed in the gateway near the entry, and the ropes deflected by sheaves so the drag is parallel to the face. The sheaves are moved toward the entry as the face retreats. In some instances the entire block has been exhausted before a cave occurred, but when necessary the roof is broken with tight posting or cribs. The gateway is kept open with cribs built as the face recedes.

The combination system has several advantages over the straight panel. A block of coal about 200 feet square is flanked on both sides with double gateways, having a very thin pillar between them. This pillar is from four to six feet thick. The block is divided by a room 12 to 14 feet wide, to serve as an escape-way. The gateways are turned off as a single neck opposite a cut through, so the scoop can be operated in either of the two parallel gateways; the hoists can therefore serve two panels with one setting. The coal is scraped to the cars on the entry. The V faces are formed with the apex in the escape-way, serving both as a safety outlet and a loose end for the faces.

A scraper unit consists of one scoop, one steel chute for delivery to car, one double-drum hoist, one motor, jacks, sheaves, ropes, etc., and a small hoist for moving the cars.

The crew is made up of five men in V and straight panels, and six men in the combination system. Tonnage per unit varies with the conditions. On short V faces, the average is about seventy tons in eight hours, and on the panel and combination systems about one hundred tons. A maximum of 125 tons is not infrequent. The coal seam averages 40 inches thick. The scraper unit, or crew, undercuts the coal, blasts, timbers, attends the scraper, cleans the faces, operates the hoist, trims the cars, moves the trip under the chute, and moves the equipment from place to place.

The cleaning of the coal is as in all mechanical loading schemes, a problem for the picking-tables. With proper blasting and other precautions, the proportion of small coal can be kept within reasonable limits.

In operating scrapers on long faces, there will now and then be trouble, and faces are frequently lost; but, on the whole, fair success has been achieved.

Gateways, and at times, entries are driven by the aid of scrapers. The coal, and in case of entries also the rock, is loaded into the scoops by hand.

Aside from the actual operation of the scraper units, there are further advantages in concentration of the work. There is better supervision; and loading in entries, allowing use of larger cars, facilitates haulage. Ventilation and drainage are also simplified. Accidents also have been reduced with this method of mining, as compared with hand loading by the room-and-pillar system.

USE OF FACE CONVEYORS IN HEADINGS AND ROOM PILLARS*

By L. H. Schnerr†

The Gray mine of The Consolidation Coal Company, located near Somerset, Pa., is entirely a conveyor mine. The results obtained are therefore free from any influence of hand-loaded sections.

The seam of coal is known as the "E" or Upper Freeport. The portion of the seam mined as marketable coal is 34 inches, and is usually without binders of any kind. Immediately above this portion of the seam are eight inches of bone, which can generally be held in place by a good system of timbering. Above this bone, we find six to 18 feet of gray slate and 30 to 50 feet of Quemahoning sandstone. The total overburden ranges from 200 to 400 feet. Immediately below the 34-inch coal seam is a 1½-inch hard bone parting, followed by 4½ inches of good coal, another 1¼-inch hard bone parting, and nine inches of dirty coal. The real bottom is a hard slate.

Short-wall machines are used for all cutting.

In our room work, we cut out the upper binder (which is just below the marketable coal) and gob the cuttings. The same is true for the cutting in the air courses and cross-cuts.

In the haulage entries, or wherever brushing is done, the cutting is done in the bottom bench of coal and the cuttings loaded out as refuse.

Our conveyors may be grouped in three classes—the main conveyor which can be extended to 300 feet, a much lighter intermediate or cross conveyor with a maximum of 175 feet, and the face conveyor which is limited to 30 feet. Both the first and second classes are chain and flight type conveyors. The third, or face conveyor, is the mat type, selected on account of its lightness and slight height, resulting in easy shoveling for the men at the face. Loading booms are provided where necessary on both the main and cross conveyors.

In entry driving, two places are driven at the same time with one common loading point. The loading boom is attached to the cross conveyor which receives the coal from the two main conveyors, one in the center of the air course and the other along the chain

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†Manager, Pennsylvania Division, Consolidation Coal Co., Somerset, Pa.

pillar rib of the haulage entry. On account of the slight width, no face conveyors are used in this set-up. Where the chain pillars are sufficiently wide to require it, a second cross conveyor is used to drive advanced cross-cuts. No loading boom is necessary on this conveyor as it delivers the coal to the main conveyor in the entry.

When the cut is made in the entry in the bottom bench, the cuttings are loaded out as refuse and the coal shot down. Care must be exercised in placing of the holes, for, unless the holes are fairly horizontal and quite close to the top bone, the coal will stick to the bone. Proper drilling of holes can be accomplished by the use of fairly light electric drills.

After shooting, the coal is loaded off the top binder giving a clean product. When this is done, the top bone is either pulled or shot down and this bone along with the portion remaining below the top binder is loaded out. Where the top bone is weak, a cut or so is left in place, temporarily timbered with light cross-bars, until the next cut of coal is removed. The final clear height is almost five feet, which is sufficient for butt entries.

Under normal conditions, a five man crew—two men in the entry, two men in the air course, and one boom man—will give us two cuts in each place per shift. The crew is under the leadership of one man who is compensated for this leadership by a specified allowance per ton. This man is held directly responsible for his entire crew; furthermore, he furnishes the necessary explosives and hand tools, with the exception of the electric coal drill. We have found that a smaller quantity of explosives is used, resulting in better sized coal, and also that tools of all kinds receive much more consideration and care since this practice has been installed.

The entry and air course are driven 300 feet beyond the loading point before the loading point is advanced. The loading point is then moved to the second cross-cut which is 200 feet distant. This gives us a minimum empty storage space of 100 feet and, since the track is laid as the entry advances, this minimum of 100 feet is increased until the maximum of 300 feet is available. No brushing is done except in the main haulage-way, except to provide necessary side-tracks at regular intervals to facilitate rapid changing of cars.

Our present system of driving rooms is called the single-room system. Only one room is driven on any one butt heading. The

rooms are 50 feet from center to center, giving a 40-foot room and a 10-foot pillar. In this system one main conveyor with loading boom and one face conveyor are used. When the room has been driven to the limit, the face conveyor is removed and 40-foot slabs are cut out of the 10-foot pillar. As we use a seven-foot cutter-bar, nothing but a shell remains to keep out the adjoining gob. The pillar is extracted very quickly, and a pillar once started is carried to completion without delay. The main conveyor into which the pillar coal is located directly is shortened after each slab is removed. The approximate time of driving a 40-foot room up to a distance of about 300 feet, and extracting the 10-foot pillar is slightly less than two weeks.

The standard room crew consists of five men, including the leader, who is invariably the machine man or cutter. The practice at the present time is for a crew to load out two cuts one day and three the next, the average therefore being five cuts each day of two shifts. We have loaded out six cuts in one day of two shifts. The day-shift and night-shift crews do not divide their tonnage equally. In some cases, however, they have mutual agreements as to the condition of the place when work is suspended for the shift. As a rule, the places are left cleaned up ready for the cutters.

We have tried several other systems of driving rooms, endeavoring to get more concentration, but due to uncertain roof conditions and the great variation in production we have standardized on the single-room system. For steady output day after day, the single room is to be preferred. Furthermore, when either physical or mechanical difficulties are encountered, the minimum of equipment is idle.

One of the first systems tried at the Gray mine was the double room with a single loading point. In that system we drove two 40-foot rooms with a 15-foot pillar between, and a 10-foot barrier pillar between the double-room set and the worked-out area. The 10-foot pillars were necessarily lost and we had considerable trouble in removing the 15-foot pillars. In each of the twin rooms we had a face conveyor. One of these delivered the coal to the main conveyor equipped with a loading boom, and the other delivered to an intermediate conveyor which discharged on a cross conveyor, which in turn, emptied on the main conveyor in the adjacent room. The required conveyor equipment included one main conveyor with loading

boom, one intermediate conveyor, one cross conveyor, and two face conveyors.

In this system, the entire operation was under the leadership of one man who sometimes had a regular crew for each room, and at other times had its special loading crew and preparation crew which worked in both rooms. The advantages of this system were more concentration and better tonnage per boom man. The disadvantages were:

1. No coal could be loaded out of the auxiliary room while the main conveyor was being extended, this operation taking between 15 and 20 minutes to perform.

2. In case of trouble, considerable equipment was necessarily idle, consequently affecting production.

3. Difficulties were encountered in getting conveyor pans, chain, and timber supplies to the working face of the auxiliary room. This was due to the fact that our intermediate conveyors are not reversible.

4. Due to the large size of the pillar between rooms, the extraction was slower, as a second cut was necessary, thus causing double shoveling of considerable coal.

Another system, which we soon discarded, was to drive a 15-foot room, bringing back 35-foot pillars on each side. This system necessitated a center-line brattice in addition to the blower fan and the hazard of open-ended pillar extraction was added. The face conveyors were not used until the pillars were ready to come back, but then two face conveyors discharged directly into one main conveyor. The advantage of this apparent concentration was counterbalanced however by the narrow work necessary in driving in advance the 15-foot room, and, since we drove the next narrow room while the previous pillars were being extracted, we had congestion on our haulageway, as we had in the same entry two loading points 95 feet from center to center.

In working out the old portions of the mine when pillars alone remain, we find it advantageous to use a combination of two light intermediate conveyors, one of which is equipped with a loading boom.

In all of our working places we make use of blowers and "ventubes" to speed the work, and room hoists and retarders for the handling of cars. Where the grades permit, we use the car retarders to good advantage. The drilling is done entirely with light electric

drills. Cutting and loading are entirely on a tonnage basis. Each particular move or change in set-up has its specified price and a standard set-up is required in all cases. Experience has taught us that we can not successfully work three eight-hour shifts a day, as a little time is necessary for proper inspection and maintenance. Furthermore it is oftentimes necessary for a crew to work past the eight-hour time to finish a cut. We find it very desirable to encourage competition among the crews. We do this by daily posting of the daily tonnage and the tonnage to date, making special mention of the winners in our Company publication.

In conclusion, let me add, that we have found that after the proper equipment has been purchased, the next most important factor in successful conveyor mining is the right spirit of co-operation developed among the men.

DISCUSSION

L. E. Young:* We all appreciate this splendid paper. Are there any questions you would like to ask Mr. Schnerr at this time? May I ask how long you have been using this equipment?

L. H. Schnerr: We started a year ago last June with this equipment. Of course, we have added a number of conveyor units to the original equipment.

L. E. Young: How much timbering is necessary in that work?

L. H. Schnerr: Our timber standards require us to set a row of posts every three feet along the room four feet apart across the room.

F. B. Dunbar:† Speaking of double entry driving with two conveyors, I assume he uses two machines, though he did not mention this point. One machine will not do as it can not be moved into the second entry. In bringing back the 25-foot or 30-foot stump, the pillar is worked at a right angle while the stump comes back at about

*Vice-President, Pittsburgh Coal Co., Pittsburgh.
†General Superintendent, Mather Collieries, Mather, Pa.

a 45-degree angle. With a 25-foot pillar by bringing it out on a 45-degree angle it is possible to get the same tonnage as they get while driving the room. The cycle on retreat is, therefore, the same as on advance, as far as tonnage is concerned.

L. E. YOUNG: A topic not on the program is suggested—the moving of supplies to the face. This was touched on in one of the papers, as well as the moving from one room to another. Possibly some of the gentlemen who are familiar with this phase of the work will tell us briefly how they accomplish the actual movement of the conveyor after one room is finished and set it up in the next room. Do you have spare equipment or do you have to take the equipment from room to room?

F. B. DUNBAR: I think I can answer that. The conveyors of the heavy type are about 250 feet in length and there are a number of types of face conveyors. It takes about ten minutes to put on a six-foot section. As the pillar retreats, the sections are taken off and loaded on the conveyor and taken down to the mouth of the room. When they get ready to move to the next set-up, the driving mechanism is moved down to the next room, where a hole has been prepared. The conveyor crew make the move and set up the equipment on the off shift and have it ready for the next day. In beginning our experiment it would take two to three shifts to make the set-up, but by improving the equipment and method the men are now able to move and make the set-up in from six to twelve hours, depending on the size of the equipment.

In entry work the conveyors are about 200 feet long and an auxiliary conveyor 80 feet long is used in driving the break throughs. In room work the conveyors are 250 to 300 feet long. The men are paid on a base rate, and paid the peak-day rate for moving the equipment.

USE OF FACE CONVEYORS IN WIDE ROOMS*

By E. A. Siemon†

This subject is one about which much can be said. However, when Dr. Young asked me to prepare this paper he told me that this meeting was to consist of short talks of approximately ten minutes each. In that period of time I shall endeavor to give you a brief description of the equipment and methods in use at the Jerome mine of the Hillman Coal & Coke Company. It is at this mine that I have had all of my experience with conveyors.

This mine works the Upper Kittanning coal. The seam dips from the south to the north anywhere from one to nine per cent. The coal varies in thickness from 40 to 60 inches, having at the top from six to 15 inches in thickness of a bone coal, which is gobbed. The overburden varies from 80 feet to more than 500 feet.

The flat entries are driven east or west 60 feet from center to center, and about 1800 feet apart. Butt or room entries, 60 feet from center to center are driven to the rise off the flat entries, 250 feet apart. Rooms are driven slightly to the rise off one entry only.

Fig. 1 shows the method of advancing entries, with location of break throughs for economical haulage.

I shall describe as briefly as possible the method of driving entries with conveyors, for we make our side-tracks as the entries are being driven. The first distance of 15 feet is taken out of the butt entries by hand loading. A conveyor is then set up at the point marked "A." This entry is advanced a distance of 138 feet to the point "B"; the cross-cut is turned at a distance of 125 feet at an angle of approximately 45 degrees and driven with a cross-cut conveyor far enough so that the other entry will cut into it as it is advanced. The main conveyor is then moved and set up at the point "C." This entry is then driven a distance of 263 feet to the point "D." A cross-cut is driven at a distance of 250 feet at an angle of 45 degrees. While this section of entry is being advanced, a track is laid in the first entry driven and through the cross-cut. The conveyor is again moved and set up at the location "B." This entry is advanced 263 feet, turning a break through at a distance of 250

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†Division General Superintendent, Hillman Coal & Coke Co., Pittsburgh.

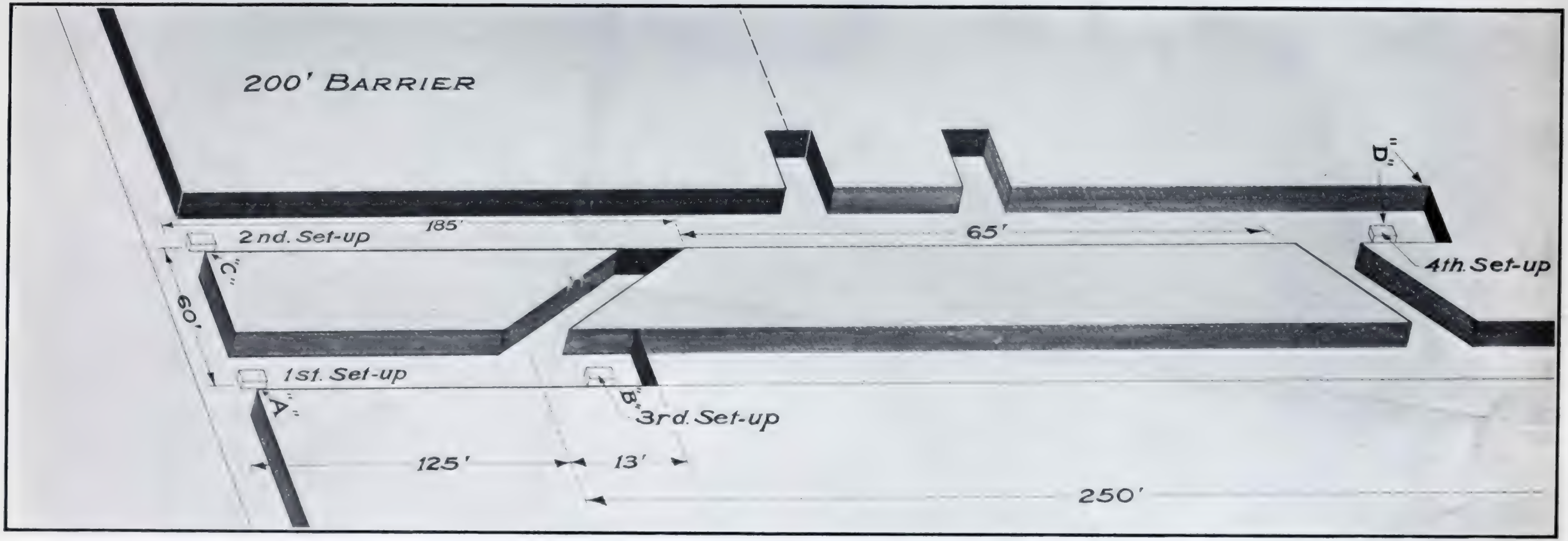

Fig. 1. Method of Advancing Entries.

feet from the first break through driven. The process of moving the conveyor from one entry to the other is continued until the entries are driven up the proper distance. Rooms are necked off one entry as the entries are being advanced.

Fig. 2 shows room and pillar work with conveyors; also the side-track for rapid changing of cars.

Only one room is worked on a butt entry at a time. It has been our experience that one room worked with a conveyor will give us as much coal as we would get from the same entry with the proper number of rooms worked by hand.

Rooms are opened off the entry 14 feet wide, and 60 feet from center to center. They are driven this width for a distance of 18 feet and are then gradually widened, reaching a width of 35 feet at a distance of 30 feet from the entry. The rib left between rooms is 25 feet thick; break throughs are driven at intervals of 100 feet. About two feet of top is taken down on the butt entry at the room neck so as to give height at the loading point.

The main conveyor consists of a loading boom which is built in the shape of a gooseneck to which is attached the main conveyor—which is made up of six-foot sections of steel troughs, or pans as we call them—and the chain, which is of the double-chain type with steel flights spaced about 24 inches apart connecting the two chains. As the room is advanced, sections are added to the main conveyor.

The main conveyor is located from six to eight feet from the straight rib or side of the room, leaving from 27 to 29 feet from the center of the main conveyor to the far side of the room. An auxiliary or face conveyor is used to convey the coal from the far side of the room to the main conveyor. We are at the present time using three different types of face conveyors, as follows:

1. A belt conveyor 12 feet long, driven by a motor of one horse-power.
2. A double-chain conveyor 12 feet long, driven by a motor of one horse-power.
3. A double-chain conveyor 22 feet long made up of two 10-foot sections and a tail section two feet long. This type of conveyor is driven by a motor of two horse-power.

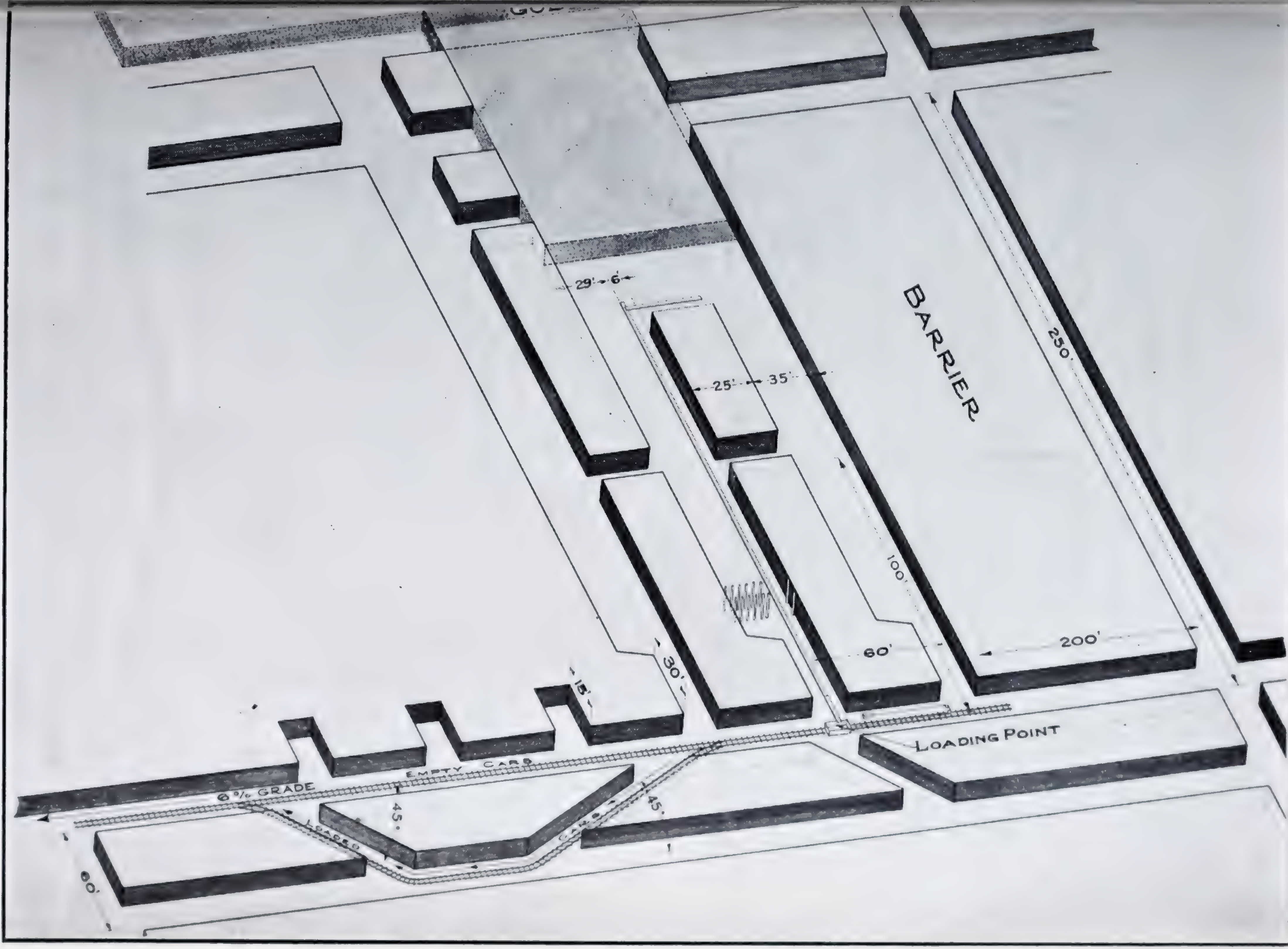

Fig. 2. Room and Pillar Work with Conveyors and Side-Track.

When the 12-foot conveyors are used at the face, two are necessary, one discharging onto the other, and finally onto the main conveyor. The motors are so located on the conveyors that they can be used on either the right or left side of the main conveyor.

On conveyors in wide room work, we use a crew of five men, one of whom is a machine operator. One man works on the butt entry at the loading point, operates the main conveyor, moves the cars and sees that they are properly loaded; the other four men work at the face, doing the cutting, drilling, blasting, loading, timbering, extending the main conveyor, and moving the face conveyors.

The cutting is from right to left. The machine cuttings are loaded onto the face conveyors and main conveyor as the face is being undercut. Two men do the drilling, while the other two are doing the undercutting. Five holes are used in a 35-foot room. The rib holes are located about 18 inches from the rib; the others are spaced eight feet apart.

After the face has been undercut, the mining machine is moved back to the right-hand side of the room and back along the side of the main conveyor out of the way. The main conveyor is extended and the face conveyors are moved into position along the face. A row of posts is set back of the face conveyor and a row of posts is also set between the face conveyors and the face of the coal to protect the face conveyors against coal rolling from the face when the coal is shot.

All the holes are loaded, a tight shot is fired first, and then the other four holes are fired at the same time. Loading is started at the right-hand side of the room. As soon as a sufficient amount of coal has been loaded out to permit the machine to move in, cutting is again started. With reasonably good conditions, three cuts can be loaded out in an eight-hour shift; however, this is more than the average.

You will note from this drawing that we drive our rooms through the chain pillar. Ribs are drawn open ended, using face conveyors to convey the coal from the rib onto the main conveyor. Two or three cuts are taken off the rib in one shift. With the rapid extraction we get with conveyors, we have found the roof action to be very much different from that which we get with hand load-

ing. We find that we get very little weight on the rib and have very little, if any, crushed coal in our conveyor sections.

I want to explain briefly our loading and haulage system. A trip of ten or fifteen cars is pushed by the locomotive up the entry past the loading point. The cars are moved past the loading point by gravity if the grade is favorable; if the grade is not favorable a small hoist is used to move the cars. The movement of the cars is controlled by the man who is located on the entry at the loading point. When the locomotive brings a trip of empty cars, they are left standing on the straight track on that section marked "empty cars." The locomotive is cut off and runs up the entry to the loaded trip; then pulls the loaded trip down the entry onto the side-track marked "loaded cars." The locomotive is then cut off the loaded trip and runs out on the straight track behind the empty cars. The empty cars are then pushed up the entry past the loading point. The locomotive then comes back to the loaded trip and takes it to the main side-track.

There are numerous advantages in conveyor mining over hand loading, especially in the low seams, the principal advantage, of course, being economy. With conveyor mining, no switches are laid in butt-entry track, no track is laid in the rooms, it is not necessary to take down top or take up bottom in the rooms to make height, haulage costs are reduced approximately 60 per cent., the same production is obtained from a very much smaller territory than is possible with hand loading methods, production per man is increased at least 50 per cent., accidents are reduced, and on account of the increase in production per man a smaller investment is necessary for the same production than would be necessary if the production were loaded entirely by hand; however, this latter saving would be partly offset by the increased investment in equipment.

Our conveyor experience covers a period of approximately 3½ years. The first conveyor was installed in the spring of 1926; at the end of that year we had three conveyors in service and produced with conveyors in that year 30,000 tons of coal. By the end of 1927, nine conveyors were in service, and 106,000 tons of conveyor coal were produced in that year. In the year 1928, with 18 conveyors in operation, 181,000 tons of conveyor coal were produced. We

now have 21 conveyors in operation, and to November 1, 1929, have produced 194,000 tons of conveyor coal, and unless something unforeseen happens we should produce about 240,000 tons of coal this year with conveyors. During the month of September this year the average production per shift was 64.4 tons with room conveyors, and 34 tons with entry conveyors.

We keep a detailed record of all our accidents and in closing I wish to give you some comparative figures showing the accident rate with conveyor mining as compared with hand loading. In the year 1928 we produced 12,929 tons per accident by conveyor mining, as compared with 4313 tons per accident by hand loading. For the first six months of this year our production by conveyors per accident was 18,128 tons, compared with 5945 tons per accident by hand loading.

HAND LOADING IN WING ROOMS*

By H. M. White†

No doubt there are those present who wonder what is meant by "wing rooms" as applied to mining. It would be of no avail to turn to the glossary of any text-book on mining, as this term is solely a local one or one coined to fit a special case. Who first began to use the term we know not but we know how it happened. About two years ago in our efforts to concentrate our working places and our working forces, we changed methods in a few places in one of our mines, where room-and-pillar methods were then in use.

We kept the straight place in the room a narrow place, about 10 feet wide, and followed up just a few feet behind with side cuts on both sides. These side cuts were wide places and were worked with open ends, which is a term well known to all coal-mining men. In this way we had three separate working places in each room, one man in each place, and each man loading into his own pit car. The significance of this is plain to us all. These side cuts some one termed as "wings" or "wing" cuts of this narrow or leading place. A little later the method of working these rooms was changed, but it established the expression "wing rooms."

By this method the coal is all taken out while the rooms are advancing. The face worked on has a total width of 32 feet and only five feet is left between adjoining rooms. This being true, such workings are necessarily limited to light covers or thin overburdens. However, we have worked and are working such rooms where the overburden is 150 feet.

With this word of explanation relative to the meaning of "wing rooms" and *where* and *how* we worked them, let us consider briefly why we used them.

One of our problems at that time was the frequent failure to place two coal loaders in one working place and have them work in harmony. We needed this to "bunch up" our workings and workmen. How well we succeeded in this you may determine from this example—in one butt entry where we ordinarily worked seven rooms,

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†Manager of Mines, Pittsburgh Coal Co., Pittsburgh.

with one man to each room, we placed 14 men and each loader had his own pit car. Here a 50 per cent. concentration was possible.

The supervision, necessary for this kind of work, is helped proportionately. The foreman over this work has his men closer to him, sees them more often, and has more men under his charge, and we all know what that means.

Our workmen realize that they can help each other in many ways, as in laying track, landing empty cars in the working places, rerailing cars, and handling heavy pieces of coal and slate.

Timber, track and track supplies, pipe, etc., all have a quick turnover, due to rooms advancing faster with no pillars to come out on retreat.

The one "wing" of these rooms, which has an open end, we believe furnishes more lumps which will bear handling, as the blasting is reduced about one-half.

The gathering haulage was done both mechanically and with animals. Where grades would permit both cars were brought out of the room at the same time by mules, and from this we realized in a large way as some of our gathering locomotives daily hauled 225 of the 1¾-ton cars.

Our undercutting machines had a 32-foot face to work on instead of 24 feet as is customary in the ordinary rooms. The machine produced about 10 tons more coal per cut in each room.

Much changing of men was required at first in order to establish in one of these "wing rooms" two men who were about the same efficiency as loaders and who worked well together. This was needed so that the two cars would be loaded at the same time and thus maintain our haulage methods. Our loaders produced for us something more than nine tons a day as compared with 7½ tons for those in our other rooms.

We have given you in a general way some of the advantages presented by the use of "wing rooms." Of course there are disadvantages also—disadvantages in the nature of limited areas where they can be worked and in the greater amount of timber required for roof supports—but despite the difficulties encountered, the method may be recommended.

DISCUSSION

L. O. LOUGEE:* Under this syetem do you draw the ribs or do they leave them in?

H. M. WHITE: These ribs are very small and they are left.

L. O. LOUGEE: How thick are they?

H. M. WHITE: They are laid out five feet. They will not average five feet because they are cut out some.

L. E. YOUNG:† As you know, the coal-mining industry and the engineering profession were honored by the election to the presidency of the American Institute of Mining and Metallurgical Engineers of one of our own very esteemed Pittsburgh gentlemen, who is with us to-day. This discussion would not be complete without a few words from Mr. Samuel A. Taylor.

S. A. TAYLOR:‡ Mr. Chairman, I was very much interested in the paper on "wing rooms" and also in noting the high efficiency of recovery, and that it could be operated under cover of about 100 to 125 feet.

Some years ago I had an operation where some changes were made in the mining operations. The maximum cover was about 150 feet, but generally it was under 100 feet. I used a scheme there that was very efficient. It possibly had some advantages as compared with this method. We reduced the room space to 33 feet from center to center, with rooms 25 feet wide, leaving ribs of seven feet. We used three rows of posts. The road posts were kept about 10 feet from the ribs and this space was kept clean along the rib side. As soon as we got up to the length of rooms of about 225 feet, we came back with the rib drawing at once. The rib being seven feet, cutter-bars were six feet, and that left a little triangle about one foot wide, which when the rib was cut was just sufficient to keep up the gob in the adjoining room. In doing the rib drawing, we cut 30 to 35

*Civil and Mining Engineer, George S. Baton & Co., Pittsburgh.
†Vice-President, Pittsburgh Coal Co., Pittsburgh.
‡Consulting Engineer, Pittsburgh.

feet of the rib at each operation. Two men would be put on this rib loading and they would load it all out in a day. In that way we drew out ribs back to the entry quite quickly and got practically all the coal.

It had a disadvantage, compared with the wing-wall method, of having an additional set of posts, yet the drawing of the posts would be practically the same in the end, because we drew out one row of posts along the road. The disadvantage was that you could not always load two wagons. Coming back, we often put in three wagons in loading out the cut. I believe it is well worth trying. We had very good success with it. It, of course, has not the advantage of wings going forward, but coming back it has the advantage of getting all the coal and getting it out cleanly and rapidly.

I give you this for what it is worth. We were working under a cover of practically 150 feet. The little triangle is just sufficient to keep up the gob from dropping in from the other side. If you get out all your road posts, the roof will break right over the end of the rib. We got nearly all our posts; only a very few were lost.

USE OF LOADING MACHINES IN THE BLOCK SYSTEM*

By Jerome C. White†

In planning for the use of machines to load coal from the Pittsburgh seam, after the type of loading machine has been decided upon, the next problem is, what mining method shall be used? Does the loading machine require anything different from the room-and-pillar method standard to the Pittsburgh district? The answer to these questions is a review of what the loading machines require of a mining system.

The requirements that mechanical loading imposes on a system of mining are:

1. Concentration. Moving distances from place to place must be kept at a minimum. This means as many places as possible closely grouped together.
2. Economical trackage lay-out so that the time required for car changes will be kept as small as possible.
3. Good roof conditions in pillar extraction so as to maintain a uniform tonnage economically and under safe working conditions. Maximum recovery of coal per acre must not be sacrificed.
4. Moderate track costs. It was decided that the coal was to be top cut to secure and maintain good roof, and sheared to obtain good preparation for the loading machines and lump coal for the market. This meant that track cutting machines would be used and that track would have to be laid to the face of every working place. Track costs, therefore, had to be considered.

The block system lay-out, as will be described in detail later, seemed to answer the above requirements as the following features show:

1. Large pillars of 90 to 100 feet square upon which to retreat, and incidentally serve as adequate support.

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2. Extreme flexibility to meet any roof conditions set up as a result of retreat work along the rib or fracture line.
3. As track is to be laid to the faces of all places the large pillars give the maximum tons per room and cross-cut turnout.

As regards track work, when the development is carefully scheduled to balance retreat, the amount of track in use can be kept to a minimum. In using this method of mining, the percentage of advance work is approximately 30 per cent., and the retreat work is approximately 70 per cent. These figures may vary at different times in practice.

The initial installation of loading machines was made in this system of mining which provides the advantages of short rooms, increased concentration, and such security as is obtained in working narrow places in solid coal. It is in retreat work along the break lines that the large percentage of solid coal proves decidedly advantageous. This is particularly true when a comparatively large number of places within a limited area must be provided for the loading machines.

Over the section now being mined mechanically the cover is about 500 feet, and varies elsewhere from 200 to 550 feet. The seam, which is from six to eight feet thick, is of a friable nature and tends to spall. As it is overlaid with draw slate which can not be held in place by ordinary means of support, it is held up by 10 to 12 inches of top coal. Above the draw slate is a fairly good roof, while the bottom is of moderately hard fire-clay.

A lay-out of the system is shown in Fig. 1, which represents several sections in different stages of development. All places are driven 12 feet wide. Butt entries are driven to the boundary; and from these entries, retreating rooms are turned, spaced 90 feet from center to center (this is varied from 90 to 120 feet) and driven to a length of 340 feet. Cross-cuts are made at intervals of 100 feet. As soon as a room has been driven to its full length, the extraction of the blocks mated to it (extending through three or four other butt entries on the same fracture line) is started in orderly sequence along a break line intersecting the line of entries at an angle of 45 degrees. Two batteries of two loading machines each work as a unit in this section.

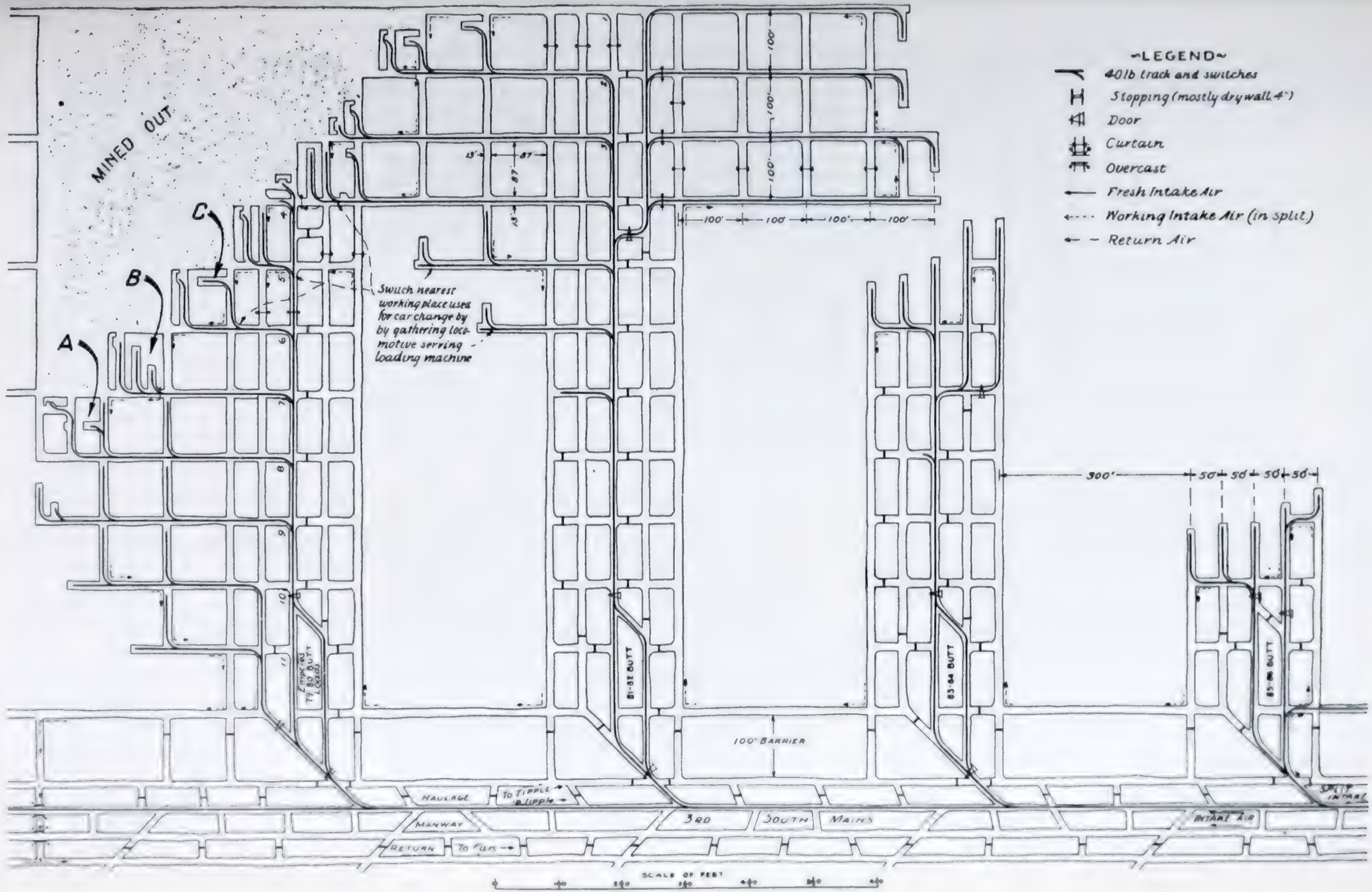

Fig. 1. Concentrated Block System for Mechanical Loading.

The method of working individual blocks is indicated in Fig. 2 which shows the various starting places.

No. 1 place can be started either in the cross-cut or on the straight side of the block. This should be determined by whether the thin ribs will stand best on the face or on the butt. This is a distinct

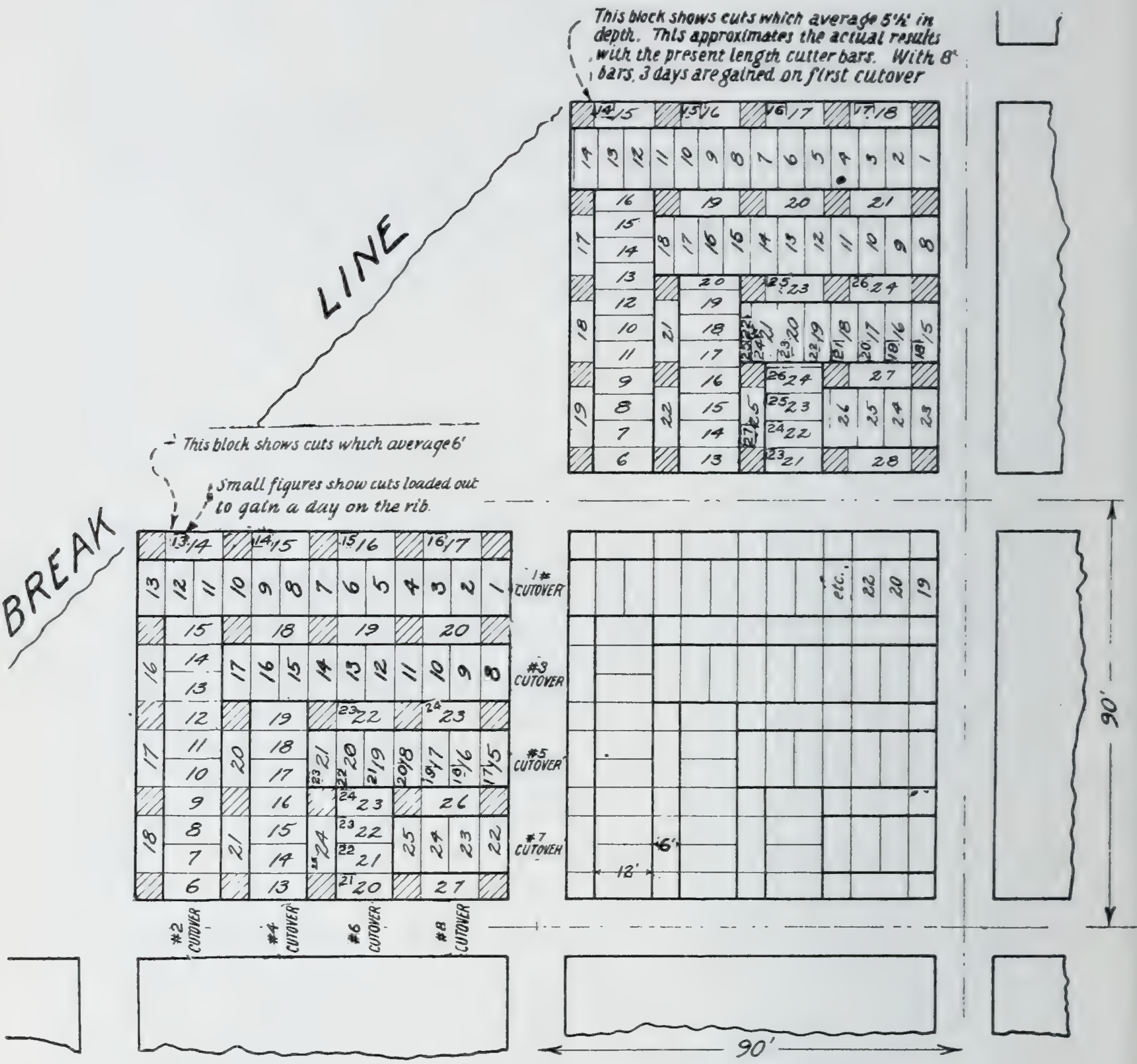

Fig. 2. Method of Working 90-Foot Blocks.

factor in some sections and advantage should be taken of it wherever such a condition is encountered. Getting the first cut-over through, without having the head coal drop, must be the objective in starting every new block. After the first cut-over is through and started back, the critical point of working out that block has been passed as each

succeeding cut-over becomes shorter than the preceding one. No trouble will be experienced on the first cut-over, provided the rib is held to the proper thickness; the shot holes next to the solid are fired first; the cut-over advances one cut every day; the top coal is not powder cut; and the posting is kept up properly. Clay veins and "horsebacks" in the roof may cause trouble when encountered but this is true of any system of mining.

No. 2 place should be started at such a time that No. 1 cut-over will have at least one cut out of the wing when No. 2 cuts through.

No. 3 place should start so that one cut will be out of No. 2 rib when it cuts through.

No. 4 place should be started so that one cut has been taken out of No. 3 rib when it cuts through.

This will make four places started on the block in 13 days. By the sketch it can be seen that it is possible to have five places for a short period of time, but probably the better plan, and the one easier of attainment, is to keep four places ready in each block. In this case, as soon as No. 1 finishes, No. 5 may be started.

One day's time can be gained in No. 1 cut through by taking out cuts 13 and 14 on the same day. This can be done on each cut-over where it is desired to gain a day.

When No. 2 finishes on the eighteenth day, the block will lose one machine place for two days. During this time, take the first two cuts out of the next block in line so that the turn can be laid without hindering the loader in this place later on. On the twenty-first day, No. 6 is cut through on the first block.

The second block should be started on the twenty-second day after completing No. 4 cut-over. From this time on, places will be started in the second block as on the preceding block.

Much flexibility can be obtained with these blocks. The principal thing in working them is to keep the cut-overs about seven or eight working days behind each other.

The shaded areas on the sketch are pick stumps. Stumps should never be larger than can be recovered by a pickman in one day. Pick work must be kept to a minimum as it will slow down the entire rib line and reduce production if allowed to accumulate.

As the rooms advance, cross-cuts are turned and a switch laid in each cross-cut. This gives the loading machine a face place and a butt place for every room. The locomotive serving the loading machine holds on to the empties and places the loads in the cross-cut. This means that the time required for car changes is kept low as the traveling distance is not more than 100 feet. In retreat work the cut-overs are not more than 100 feet long, and vary from 20 to 30 feet from center to center. The number of cut-overs with their respective pillars ranges from two to five to a room. This number of loading places near together provides short moving distances for loading machines and for locomotives in making car changes. The lengths of these cut-overs with their retreating rib is such that costs are reasonable; that is, they come within standards of what track costs should be.

Top cutting is primarily intended to facilitate the holding of top coal and to preserve, by protecting the roof against shattering blows, whatever self-sustaining powers it may have. This top coal is very tender, however, and this presents another condition—roof control along the rib line must be as nearly perfect as possible to keep pressure off the roof, as the top coal will blister and fall with the slightest weight and the overlying draw slate will come with it. This is one of the reasons that flexibility was cited as a requisite of a system of mining in the early part of this paper. Flexibility is required so that in case any pressure is evident the number of working places can be adjusted until the pressure is brought under control.

As approximately 70 per cent. of block system mining is retreat work, and as this top coal roof is very tender, it is absolutely necessary that good, clean breaks be made so that no pressure whatever will ride over the fracture line to the open working places previously developed. Just as few places as possible must, therefore, be opened in advance of being retreated; yet it is necessary to provide the maximum number of open places, either advance or retreat, if the loading machines are to be assured of a uniform standard tonnage.

The most critical time in the development of a large retreat line is just before the major break occurs. While the new retreat line is moving back and only the immediate overlying strata have fallen, the higher, heavier, and stronger overlying strata seem to want to bend and ride back over the break line and onto the already opened

producing area. This phenomenon has been described by such engineers as R. Dawson Hall, H. F. McCullough, and R. Y. Williams, and, of course, many others. Beyond this mention of it I shall spend no more time on this subject as its causes are a matter of controversy. Each of these men discusses the subject of support along the fracture line as to whether it should be rigid or yielding. The point I want to bring out, however, is that the large block of solid coal along the rib line affords an almost perfect rigid support over which the overlying strata are broken cleanly and with a minimum of bending.

During the early stages of the retreat line made by the block system being described, the above point was recognized, and we were very cautious until we were sure that the major break had been obtained. The amount of open work was kept to a minimum, even, at times, to the detriment of loading-machine production. Only two places in each block were driven—one face place and one butt place—these being, of course, at right angles to each other. Careful attention was given to making clean local falls and to seeing that no standing timber was left in the gob areas. The major break occurred, we believe, at about 300 feet from the origin of the retreat line. After this there was a noticeable relief of roof pressure. From this point on, the number of cut-overs per block was increased and it now varies between three and five per room. It is this feature of being able to adjust quickly the number of places being opened to actual conditions imposed by roof pressure that makes the use of the block system particularly valuable.

ALLOY STEELS*

By E. C. Smith†

Without attempting legal exactitude alloy steel may be defined as a steel, the special properties of which are dependent on the addition of one or more alloying elements. To make this clearer requires definition of the underlying material, steel.

Excluding blister steel, which is carburized wrought-iron, steel may be defined as iron and carbon, cast in an initially malleable mass. Thus we have, for steel, three essentials—iron, carbon, and initial malleability. For an alloy steel we have these three plus a special property or properties dependent on the addition of one or more alloying elements. You will see that the discussion of alloy steels is based on very inexact limitations.

As a fair premise let us say that alloy steels are special steels and that chemical composition may be less important than many other factors. As it would require a rather elaborate volume to cover the field of special steels no attempt will be made at this time to cover the history of the subject, and only such materials will be considered as are in regular production in a tonnage way, and even this group can be but hastily scanned.

It is common knowledge that the luxuries of one year become the staples of the next. Where skill and capital combine to produce a special material at a relatively low cost, a widespread application results. This is especially true of the alloy steels, which until recently have been luxury steels. The effect of lowering prices and increasing production in this country, has been to bring the entire steel industry to a degree of special manufacture not contemplated a few years ago. For this reason, alloy or special steels are of more than usual interest to manufacturers of steel, and it becomes important to study the present design of plants, giving special consideration to their adaptability to the requirements of the future. We must expect radical changes in lay-out and design of mills. Flexibility always brings with it major problems of control, and even the type of personnel may have to change.

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The rather unsafe definition of alloy steels did not include any limitation as to process, and we find all of the existing commercial methods responsible for some tonnage of special steels. Essentially the production comes from two sources—the basic open-hearth process and the arc electric process. In the immediate future there will be interesting additions to the present tonnage of induction-furnace material with the trend toward high frequency where small lots are desired, and low frequency where tonnage is important. It does not seem probable that any fewer methods will be used, however narrow the present field is for certain processes.

In melting practice we are soon to benefit from the study of the physical chemistry of steel making—in fact, we are already doing so. It is to be expected that more direct methods will be worked out in the near future. Steel scrap and pig-iron may not be the essentials of the luxury steel. Sponge iron may be the basis of a new steel making. Certainly better knowledge of melting practice will permit higher quantities of hot metal to be converted into steels of any desired qualities. It is reasonable to expect the special steel to carry the burden of development of these new processes, and, for that reason, they should be studied, although the ultimate use of some of them may be slight.

At present, special steels are the product of processes that are essentially the reworking of steel scrap, and this means that, to date, special steels are not the result of an operation in which the essential is to convert raw pig-iron into salable steel.

Between the tonnage producer and the specialty maker there is no vast difference. The basis of both is blast-furnace iron, but the special steel uses less of it and more scrap. In the induction units nothing but steel scrap and alloys are required; in the arc furnace a small amount of pig-iron is used; in the open-hearth furnace about half the charge is pig-iron. In some work it may be desirable to use it cold; in other cases it may be used hot, but usually a more uniform quality of pig-iron must be supplied. It does not seem that any direct process is sufficiently established to change this status immediately.

The special steel business is a large consumer of scrap. It can reasonably be expected that our present hazy ideas of scrap and its relation to finished product will be clearly defined in the near future. That this is reasonable is founded upon the knowledge that certain

steels require not only the choice heavy scrap so desired now, but that others will require very light scrap, of which there is no definite supply at present. With increasing knowledge of scrap characteristics will come a better utilization of the present narrowing supply.

It has been pointed out that no vast difference exists between tonnage and special steels. The increasing value of special steels warrants increased care, and thus it is usual to encounter certain refinements which are rapidly spreading to the tonnage industry. Less iron-ore is used in the open-hearth work, with burnt lime, more clean-up alloys, and more time. All the ingots are sink-head ingots, and a large number are big-end-up ingots. More attention is given to the work for the reason that the product is worth more money. The same skilled melting practice is used, but a little less pressure is put upon the men for production, and considerably more pressure is applied to produce steels of certain physical characteristics—shallow or deep hardening steels, and steels which anneal easily, or possess some other special quality.

The present trend of intangibles in specifications for alloy steel must be viewed with concern by the tonnage producer. The alloys added, it would seem, include everything which alloys with iron, and many things which are supposed to combine only with the slag. To the outsider viewing the marvelous array of elements used, the steel maker must be considered a very learned man. To the insider it is known that the master of any single element is the learned man.

Without attempting to discuss all the manufacturing problems, the alloys used divide themselves into two groups; those which do not oxidize during melting, and those which do oxidize.

The open-hearth process, which is an oxidizing process, does not have the same limitations with non-oxidizing alloys that exist with the oxidizable elements. It is thus natural to expect nickel, molybdenum, and copper to be commonly used in the open-hearth furnace. It is equally reasonable to expect chromium, vanadium, and tungsten alloys to be at their best in electrc furnaces. The non-oxidizing alloys may be added at any stage of the heat; the others are protected from loss by various special practices, but are usually late furnace or ladle additions.

With alloy steels the pouring practice differs from that with tonnage production only in the same way that melting differs. The

product is expensive and must be cared for. Sink-head ingots rather smaller than the usual ingots, are common. In certain cases, the ratio of length to cross-section is less but hardly approaches ideal conditions, since most of the ingots require lengths for rolling-mill handling. It would seem that this phase of the industry could stand much more study. Certain ingot producers who do not roll their product, have accomplished a good deal by study of their pouring practice. In the main, it might be said that alloy steels for automotive products are cast in fluted ingots the total weight of which, including the sink-head, is less than three tons.

The essentials of rolling are similar to those of tonnage products. The protection feature in this case means smooth rolls in all cases, less reduction, and generally very much more exact rolling temperatures. These factors are more difficult to accomplish than in tonnage production, due to the smaller orders and frequent changes.

The surface preparation of alloy products is more thorough than with the tonnage steels, but not more so than is the case with good seamless-tube stock. The chipping and grinding departments of an alloy plant are usually very large.

Returning to our rather unstable definition that the alloy steel is a special steel with properties depending upon the addition of one or more alloying elements, we may fairly ask where the commercial steel stops and the special starts. This is a question which it is impossible to answer directly. Nickel to the extent of 0.05 per cent. is of no use in hardening, but is very nasty when butt welding is to be done. A discussion of the characteristics of the alloying elements and their actions will give a better ground for judgment.

An examination of the elements alloyed with iron, shows that a certain order is present, and the study of this would enable the prediction that future combinations will be adaptations of the present. Iron and nickel are in the same family, and can be considered the underlying material and really discussed as iron.

In the periodic table, the series of metals with atomic numbers starting with 22 and including 25 are all alloyed with iron. Titanium 22, vanadium 23, chromium 24, and manganese 25, form a group of somewhat similar alloying metals. Iron is deoxidized by the group of elements the atomic numbers of which start with 12 and include 15. Magnesium 12, aluminium 13, silicon 14, and phosphorus 15, are

a group of alloying materials somewhat similar in their action. Iron is alloyed mainly by group 6 of the periodic system, which group contains chromium, molybdenum, tungsten, and uranium. Since these three groups have been investigated, it would appear reasonable to predict this limit for alloy combinations for some years.

As indicated earlier, nickel and iron are natural alloying elements. They are found alloyed in nature, and in meteorites their ores are often found associated. It was thus natural that nickel steels were developed, and it is really strange that they were not developed until so recently.

Nickel steels have been developed to form a series from the soft grades to oil-hardening grades, but they do not find application in the fields of very high hardness such as ball steels, spring steels, tool-steels, etc. Nickel lowers the temperature at which steel hardens, and raises the strength without sacrifice of ductility. Taking advantage of this, nickel steel may be used to lower the quenching temperature, and this decreases scaling and distortion during hardening.

Nickel should find wide use where the finished part is machined and heat treated. Carburized parts are distinctly in this class, and it is natural to find this field dominated by nickel steels. Nickel is expensive and does not tend to high hardness. It is natural to expect compromises to be made by addition of other alloying elements. Hardeners such as chromium can be added, producing the chrome-nickel series. This series has been developed over the same range as the simple nickels from carburizing steels to the grades for oil-hardened gears, but they are not used in the high-hardness parts.

In the low-chrome grades, such as 1½ nickel and ½ chromium, they are good commercial steels. The carburizing grades are harder to machine and more difficult to treat than the 3½ nickels, but are commercially satisfactory. The high-nickel chromes of the old Krupp type are wonderful steels, but they are very expensive and very sensitive to treatment. They are limited to use in applications which can stand rigid piece inspection and definite study of brittleness. High-nickel chromes are standard steels for intricate sections or treated parts of large section, such as big gears, dies, intricate cranks, etc.

Two other nickel combinations are common enough to bring out the character of the added alloying elements. Nickel-chrome-vanadium steel in the carburizing range is one to which the addition of

vanadium broadens the quenching range, in which a fine case structure may be obtained. Nickel-molybdenum steel is indicated where sheer hardness is the desideratum. The nickel-steel quench is naturally slow, and the addition of molybdenum speeds this, permitting nickel-molybdenum hardness approaching the true hard steels. The discussion of nickel steels may thus be considered the key to the character of the alloying elements.

Vanadium is essentially insurance in heat treatment. It is best known as chrome vanadium, where it broadens the treating ranges sufficiently to permit high-pressure heat treatment. Its natural field is in such work as can not be exactly controlled. Large variation of section, extremely rapid forging operations, very high quenching heats, and all types of working that are doubtful, can be safeguarded by the use of vanadium.

Molybdenum has not located its natural field. Best known as chrome molybdenum, it finds considerable use as a cheap water-hardened steel for machining after treatment. It is machined commercially at physical properties as high as any known steel. The use of chrome-molybdenum steels in the other ranges of composition has been limited, and results are not so satisfactory. Nickel molybdenum and nickel chrome molybdenum are both commercially used, and both will develop wide fields of application. Limited at present to definitely controlled manufacturing processes where the sensitive hardening combination can be handled, they furnish die-blocks, and parts for aëroplane engines. They will develop a field in steels in which the advantage of change of volume during drawing is used to produce hard, tough parts, such as die-blocks, and carbonized bearings.

So far we have really considered iron-nickel alloys, and we noted early that chromium is widely used. Chromium, like manganese, is really a structure-changing alloy. It is nearly universal as an alloy steel, and the tonnage of purely chromium types exceeds that of any other alloy steel. Chromium steels form the only complete series of alloy steels. They are used from the carburizing grades to the ball steels. The compositions vary from very small amounts to large amounts, exceeding the nickel addition. In late years considerable development of chrome-iron alloys as semi-steels and corrosion-resisting products, has broadened the field of this useful alloy. A dis-

cussion of the characteristics will serve to outline the questions which must be answered when choosing an alloy steel.

From the manufacturing end, these steels have an interesting history. They seemed very simple to make and proved very difficult. Chrome steels, like carbon steels, demonstrate daily that quantative chemistry is a poor guide to the ultimate qualities of a steel. Modern metallurgy has been forced to admit that manufacturing practice is an essential in making chromium steels.

Starting with the carbonizing grades, they are at a disadvantage due to the temperature required for quenching; they are properly treated only with lead or fused salts; open fuel furnaces or electric furnaces should not be used. The high quenching temperature and the high hardness developed during quenching are associated with distortion. The natural field is in full hard work, which is ground to size after treatment—piston pins, carbonized ball races, etc.

The water-hardening chromium steels are the most important group of alloy steels now in use. Strictly speaking, chrome vanadium, chrome molybdenum and chrome silico-manganese are included in this list. They are as easily handled in forging as carbon steels and more easily heat treated. They have all the advantages of carbon steels and are not so widely variable in treatment. They are the alloy steels of big production jobs where machine work is done subsequently to treatment, as on axles, knuckles, etc. As the carbon increases, they are water hardening only in large sections and are oil hardening in small sections. In the medium carbon ranges, say 0.40 to 0.55, they form the backbone of the gear industry, where gears are cut and hardened directly in oil. The business of passenger automobile transmission is founded upon such steels. In gears they are at a slight disadvantage in the modern electric-heat units; scale is formed and prevents good quenching. In salt baths or lead they harden very well.

Above 0.60 carbon up to 0.85, low-chrome steels are common as simple tool-steels. Above 0.90 carbon with higher chrome, they dominate the field of hard steels, such as bearing steels. In this field they present many interesting commercial problems. The few points mentioned serve to attract attention to a few of the factors which may or should be given consideration in the selection of an alloy steel—composition, such as nickel, chrome, molybdenum, vanadium,

or the combination of any of these; method of manufacture, whether rolled, forged, machined, carburized, or heat treated, and the proper type of equipment; physical requirements, such as texture, ability to distribute stress or tendency to localize stress; peculiar conditions of structure that have been found so important outside the field of steel, as in tungsten wire; steels that shrink, expand, or hold their size.

How are these factors related, weighed, sorted and application made? How often are the factors considered? Is steel selected and do engineers really care whether the product fits the job? Do metallurgical men interest themselves in the factors of selection?

Repeating the high spots of chemistry, we may say carbon steels for shallow hardness and high ability to distribute stress; nickel steels for lowered hardening temperatures and good distribution of stress; chrome steels for high hardness and ability to localize stress; vanadium as insurance; molybdenum with chrome in simple machined parts, and with nickel in parts requiring more hardness.

Beyond chemistry, probably the next important point is texture, grain size, or structure—that undefined property of being able to fulfill certain requirements; a gear steel that forges easily in districts where light hammers are present; a carbon steel that blanks properly; a nickel steel that can be carbonized and will stand much bending. This important point of proper structure can seldom be specified and frequently causes much trouble.

Discussion of specific products will assist in showing points that may require consideration. Transmission gears used in automotive work are familiar to all. They cover practically the ranges of composition listed in the specifications of the Society of Automotive Engineers. There must be some reason for the wide variation in composition. A discussion of second-speed gears will focus the attention on a known part. The mass-production speed gear is based on an economical steel that can be processed by simple methods. The field is dominated by chrome steels. The related chrome vanadium may be considered an insured chrome steel. Chrome steels are economical. They can be annealed very rapidly in continuous furnaces, even in the 0.50 carbon oil-hardening range. They anneal very uniformly, cut uniformly, harden well, and give service. What are the debits? If so perfect, why not all chrome gears?

Chrome steels have high critical point and therefore high hardening temperature. This means that they must be protected during heating, and preferably heated in lead or fused salt. Chrome steels harden deeply and localize stress; they may therefore be brittle. They anneal so easily that they may overanneal, and be slow cutting and slow in solution rate during hardening heat. This is especially true of the vanadium branch of the family. If high critical point is a problem, this is best removed by the use of nickel steel. Nickel steel has a low critical point, but is slow to anneal, hardens only fairly well, and is expensive. If the expense can be borne, the addition of sufficient nickel to the chrome steel should solve both problems, bearing in mind that any compromise is usually at the expense of the best of the combination. Nickel-chrome gears are expensive, but if free from the stress concentration of the chrome and the indefinite hardening of the nickel, they are wonderful.

If design is a factor in stress concentration—and if hardness must be maximum—we must drop the simple oil-hardening steel and choose from the softer steels. The hardness must be obtained by carbonizing. Here again we choose chrome steel when hardness governs, and nickel where quenching is difficult, and again use the combination as a compromise. Thus we find nickel-chrome truck gears where size, design, and duty demand combination and a more complicated method of treatment. Where the stress is less, five per cent. nickel may be used. In passenger automobile service the complicated section gear would be carbonized 3½ per cent. nickel. There has been little use of either vanadium or molybdenum in the carbonized transmission, but both are common in the carbonized differential parts.

After selecting the material, is it possible to choose at random from equipment for the manufacturing and treating operations? Can an oil-hardened transmission be produced in a plant that has been producing carbonized transmissions? A great many plants have faced the latter problem in the last few years. The short-tooth transmission gear could use oil-hardened steel; the transmission could be produced much more cheaply and could meet many requirements.

Can the carbonizing furnaces be used to anneal? Can the leadpots be used? Do we have to provide new furnaces? Should they be batch or continuous, special or regular? These are definite questions. Anneal for machine work means anneal for structure. Car-

bonizing furnaces hold high heats for long periods. Structural anneals demand flexible control of annealing heat, and the batch furnace can not accomplish this. If batch furnaces must be used, the anneal should be made of quenched material, such as 3½ per cent. nickel. Chrome steel is usually ruled out of batch annealing.

Lead-pots and salt baths are very satisfactory for treating transmission work. They usually exceed the electric furnace results by wide margins. Suppose the proper balance has been effected. Suppose the properly designed part was produced by a sequence of properly co-ordinated operations including the treatment. How much is to be gained? It is not uncommon to see the useful life increased from ten to one hundred times the accepted value.

During recent years, the special-steel industry has taken on a rather interesting aspect, due to the production of two groups of steel. It has been calculated that the strength of iron is about 1,000,000 pounds per square inch. Recently published figures run as high as 1,800,000 pounds. Translating this into usable terms, we are getting about 10 per cent. of the strength in our good steels and about five per cent. in our simple products. There are very good grounds for feeling that this is true. The strength of a wire rope in tension is indicative of possibilities. When gear steel, with the finest treatment, can show the strength of wire we will have accomplished much.

There is much about a piece of steel to indicate that it is a lot of short wires which approximate a wire net filled with clippings of wire in rather short pieces. Each piece is quite strong, but the strength of the aggregate depends upon our ability to intermingle the pieces or provide some filler with strength of such order that the short wires are held together. That this is possible looks reasonable in the study of the high alloys, such as 15 per cent. chrome or, more strangely, from the observation of a nitrogen-hardened product. The strength of a 0.15 carbon steel with about 12 per cent. chrome, under certain conditions of hardening, exceeds the best properties developed by treatment of material for gears or aviation crankshafts, for instance. To date, heat treatments from furnaces do not produce similar results.

The physical properties of certain high-chrome die steels produced regularly in this district are of equal interest. The ability of a nitrided surface to carry load, indicates a strength on the order of

perfect metal contact. It is for this reason that the two new endeavors will stand searching inquiry. From either may come the secret of how to make an inch round as strong per unit area as a music wire is to-day.

Another interesting reason for the study of these new endeavors is that both of them enter the field of rust resistance. Iron has always burned up, slowly to be sure, but surely as time. Nitrided surfaces are nearly akin to a non-metallic type of surface. The surface of the high alloyed products approaches that of the noble metals. If it is true that stability of surface is associated with continuity of structure, there may be a closer relation between the soft, resistant surface of a chrome-nickel alloy and the hard surface of a nitrided specimen, than is apparent at first glance.

In closing, it may be of interest to discuss for a moment the chrome-nickel alloy used for resisting corrosion and rust. It is of special interest to-day, in that it is replacing plated decorations in the Ford car in one direction and replacing stone and similar materials for building decorations in a vastly different field. In its essential it is an electric-furnace product with 0.10 per cent. carbon, 18 per cent. chrome, and eight per cent. nickel, and in many ways more like a brass than a steel. It offers many problems in manufacture, and many more in its applications. It is produced in the major quantities in arc furnaces from steel scrap and ferro-chrome, the nickel being electrolytic nickel. It is poured in conventional ingots rolled in ordinary mills, rolled to sheets in ordinary mills differing not so fundamentally in any respect. It is pickled in stronger solutions—about 20 per cent. hydrochloric acid, to which may have been added enough nitric acid to produce chlorine; in fact, in certain cases, an aqua regia pickle is used. It requires nitric acid treatment to stabilize the surfaces and render it immune to rusting, the greatest fault of other steels. It has an immense future. In a few years the workmen who handle this material will determine the essential points, and it appears reasonable to forecast a considerable reduction in price.

In many fields the noble-metal type of the chrome-nickel will not be required, but simpler combinations will appear. It is to be hoped that larger structures of more pleasing appearance with indefinite life can be made entirely of steel, developed about the studies of these, the more recent major alloy steels.

DISCUSSION

S. S. WALES, *Chairman:** We appreciate Mr. Smith's very able paper.

There is just one point on which the speaker did not touch, that I would like to bring to your attention—the aid which alloy steels have been to the rest of the steel business. When we started in with steel, it was a great improvement over wrought-iron, so for a long time, we accepted it as good enough in quality and worked rather to quantity production. Then came the automobile, which had to have steel of higher strength to stand increased stresses and we began to develop alloy steel. We immediately discovered a number of things about the manufacture of common steel that made it a lot better. So the two were sort of "speeded up" together, alloy steel leading and plain steel trying to catch up; then plain steel going ahead for some purposes and alloy steel working harder; then both working together until to-day we put out a better grade of common steel than we did before we had our alloy competitors.

T. J. LUTZ:† Did I understand you to say that this 0.05 per cent. of nickel affects the welding properties?

E. C. SMITH: We make an advertised product and I do not like to refer to it in a meeting of this kind, but I might refer to the case of copper-molybdenum combination in which the welding apparently depends on the addition of a very small amount of nickel. We found that in certain types of butt welding 0.05 per cent. of nickel was the turning point. Below 0.05 per cent. it was commercially satisfactory. Above 0.05 per cent. many of the welds were bad.

T. J. LUTZ: Does that apply to electric welding?

E. C. SMITH: No. We have welded a very high chrome-nickel alloy fairly successfully with electricity.

*Chief Electrical Engineer, Carnegie Steel Co., Pittsburgh.
†Manager of Metallurgy and Inspection, Superior Steel Corporation, Pittsburgh.

C. M. JOHNSON:* What is the merit of steel with 18 per cent. chromium, eight per cent. nickel, and 0.07 per cent. carbon as compared with the same alloy with 0.1 to 0.12 per cent. carbon? Is there any real value in having 0.07 per cent. carbon rather than 0.1 to 0.12 per cent.?

E. C. SMITH: May I ask the specific field in which you propose to use it?

C. M. JOHNSON: For seamless tubing.

E. C. SMITH: The only place in which you would want a very low carbon, is where there is continuous high temperature and high pressure such as in oil-cracking units.

C. M. JOHNSON: Do you believe that there is any definite evidence of a justifiable high limit of 0.07 per cent. carbon?

E. C. SMITH: I believe there would be less possibility of carbid precipitation with 0.07 per cent. carbon, but there is little positive evidence on this side of the ocean as to the definite requirements.

C. M. JOHNSON: How much copper was in that nickel-chromium steel with which you tried the butt welding?

E. C. SMITH: The copper content is 0.5 per cent. Apparently the important point was a little difference in the nickel. I mentioned that only to try to bring out the point that you must define the limitations surrounding the particular case. Each one will be limited by its specific application.

C. M. JOHNSON: Then, as I understand it, had there been no copper there, the 0.05 nickel would have had the same effect on the welding.

E. C. SMITH: It does on very light tubing in butt welding, no copper being present. Coming back to Mr. Wales's comment on plain

*Director, Research and Metallurgical Departments, Park Works, Crucible Steel Co. of America, Pittsburgh.

carbon steel versus alloy steel, there is one field other than wire rope, where the alloy steel is absolutely ruled out, and that is in some of the valve springs of aviation engines. So though the alloy steel is ahead in some respects, there are a great many fields where the alloy steel man has not been able to catch up to the carbon steel.

A. W. DEMMLER:* Does the six per cent. chrome steel have any possibility of replacing to any extent the combination of 18 per cent. chromium and eight per cent. nickel?

E. C. SMITH: I feel that it will. I do not believe they will carry it into all of the operations where they have carried the more expensive chrome nickel. I believe it will be a compromise between the expensive chrome nickel and the simple carbon steel.

S. S. WALES: How far have you carried the copper alloys?

E. C. SMITH: Not beyond 0.5 per cent. We made some experimental steels with copper in the neighborhood of one per cent. with very sad results. It was all right in very small ingots with heavy chilling, but was not commercially satisfactory when we brought it up to ingot size. If any one knows of a definite product of one or more per cent. of copper in 25- or 30-inch ingots I would like to know of it, because I have been criticized by a man who thought he had a very cheap alloy steel, and I was unable to make it in a usable, uniform, heat-treating steel.

S. S. WALES: With copper soluble in iron up to seven per cent. and iron soluble in copper up to three per cent., it would seem that it would alloy within the range of solubility.

E. C. SMITH: My impression of the copper steels is that the coring (which you see in nickel steel) is aggravated to such a degree that it is impossible to anneal commercially. Equilibrium diagrams would indicate that they do alloy, but commercially I was not able to remove this coring effect by any heat treatment I was able to devise.

*Metallurgist, Vanadium Corporation of America, Bridgeville, Pa.

C. M. Johnson: What is your main application for steel with 0.5 per cent. copper?

E. C. Smith: In galvanized sheet; not as a structural steel. We have made some alloy steel of 0.4 per cent. copper, in a material of much higher tensile strength, but that is the only copper steel of any consequence that we manufacture.

D. T. Haddock:* I have heard the theory advanced that it is dangerous to attempt to weld steel of 16 to 18 per cent. chromium, as the change in structure immediately in the vicinity of the weld makes it brittle.

E. C. Smith: In a great many cases that is absolutely the truth. To-day I was looking at a welded tank bottom where a place about four feet long had broken about ¼ inch back of the weld. That was a straight 18 per cent. chrome steel. Had that been of the chrome-nickel type, the inner lining of that tank would not have shown any break at all.

D. T. Haddock: What change has occurred in the structure of the steel during welding?

E. C. Smith: Recrystallization in the sheet rather than in the weld. The damage is not so apparent in the weld, as it is in the untouched material immediately adjacent to the weld.

D. T. Haddock: Isn't it true that there have been a large number of tanks built from 18 per cent. chromium steel?

E. C. Smith: Yes, where the welding was done skilfully. We have a great many tanks lined with straight 18 per cent. chromium steel, but to compare the ductility with that of the 18 per cent. chromium and eight per cent. nickel, is to put it at a very serious disadvantage.

*Special Representative, American Sheet and Tin Plate Co., Pittsburgh.

W. H. McCune:* Isn't there more skill required in the welding of the straight chromium?

E. C. Smith: In my opinion, very much more so. As a specific example, we built of stainless-steel plate a box (for nitriding) more than 20 feet long and three feet in cross-section. We had both materials and we chose 18 per cent. chromium and eight per cent. nickel, because we felt that we would get a ductile weld, and our plate in operation would not give us any trouble. Had we not felt that it was easier to weld, we would have selected the less expensive material.

A. W. Demmler: Was a coated rod used in that welding?

E. C. Smith: Yes. I am not familiar with the coating, but I remember that the best results we had on those big tanks was with a welding wire that came from England through the Babcock & Wilcox Company—an asbestos-wound heavily coated rod, with an extra coating around it.

C. W. Daubert:† With a high chrome-nickel casting which is used primarily for high-temperature work, is it possible to get a strong weld with either electric or gas welding?

E. C. Smith: In our judgment it is safer not to weld. I can best answer that by citing the example of a furnace we are using, which is an alloy of 25 per cent. nickel, 25 per cent. chromium. The first furnaces were made of welded members; the later furnaces have been made of bolted members. Our reason was that we had sufficient breakage of those welds to be a serious impediment to operation. That does not mean that it can not be done. Our experience has been that it is more satisfactory to make these units and fasten them by some other method than welding. Last night I saw a producing unit shut down due to breaking a series of welds of an alloy virtually identical with the one you mention. We have a normalizing furnace with about 100 feet of alloy going through it in which the units are not

*Assistant Metallurgical Engineer, American Sheet and Tin Plate Co., Pittsburgh.
†Engineering Department, American Sheet and Tin Plate Co., Pittsburgh.

welded integrally. We have other furnaces with 45 feet of welded length. The normalizing furnace has been excellent since the long non-welded members were put in. We believe that unnecessary welding is foolish.

D. T. HADDOCK: What is the critical temperature beyond which it is unsafe to go in order to make a satisfactory weld of these alloys?

E. C. SMITH: I feel that in chromium steels any welding temperature will produce grain growth adjacent to the weld to such a degree that it will be less ductile. In the chromium nickel if there is a loss of ductility, it is not to a degree that is serious. In the comparison of the two the chrome has a very serious disadvantage. The same characteristics to a certain degree obtain in carbon steel. A weld in common carbon strip may have a very brittle zone immediately back of the weld. Plain chromium acts very much like the simple carbon with relation to welding. Chromium nickel produces a ductile weld that is practically austenitic. It has an extremely high elongation like manganese steel. I can not tell you anything as to the specific temperatures of the zone behind the weld. I would say that the chromium steel makes a poor weld, using chromium nickel as a basis of commercial comparison.

W. M. AUSTIN:* I understand that steels containing higher percentages of silicon and manganese than usually found in carbon steels, have been very successful in elliptical and semi-elliptical springs for vehicles, but that no gain in physical properties can be found in alloy helical springs of large-diameter wire, such as railway car springs.

Carbon steel helical springs are often tempered at a height greater than the final free height of the spring. After tempering they are compressed solid several times and take a permanent set to the desired free height. The surging of the spring puts internal stresses into the spring material when the spring is without external load. The object of the surging is to increase the load which the

*Engineer, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

spring can sustain without taking additional permanent set. It is well known to spring makers that carbon steel springs that have had considerable set put in them can not be surged for very long from no load to near solid without fatigue failure. They also know that if the minimum load is made a large enough percentage of the final load, failure is not likely to occur even after 100,000,000 operations.

It would be interesting to know the details of the fatigue failure of alloy springs of small-diameter wire—the maximum and minimum loads; the behavior of the carbon steel spring, and also of the alloy steel spring; the question of whether either or both springs took permanent set before failure from fatigue took place. The question of whether the fatigue was accelerated by giving the springs a reversal of load would also be interesting, as well as the chemical composition of the alloy steel and carbon steel springs that were tested.

E. C. Smith: It is my personal opinion that there is no advantage, but a very serious disadvantage in the helical spring made from alloy steel. One experience that was fairly well gone through brought out the surprising result that the better the material looked in tensile tests in the laboratory, the worse it looked in the helical spring in a simple endurance test, and not by a small value, but of the order of 5000 compressions as against 200,000 for a piece of simple railroad spring steel. I should say under these circumstances, there is not only no advantages but a serious disadvantage. That disadvantage apparently does not hold in the leaf spring on account of the very thin section, and I believe on account of the inability of the very thin section to store the terrific residual stresses of the long helical spring. One reason was brought out by the American Steel and Wire Company in x-ray investigations of annealing. It was found that in drawn wire—that is the material in small helical springs—the annealing temperature to remove the effect of the cold working has to be very high. I am certain from the report, that a microscope will not tell when a piece of drawn wire has been fully annealed. Therefore, a great deal of alloyed material has been put into service, heat treated with the stresses remaining from the original cold-drawing operation.

SOIL MECHANICS APPLIED TO FOUNDATION DESIGN*

By Glennon Gilboy†

Nature of the Problem. The ultimate criterion governing the amount of load which may safely be applied to the soil supporting a structure is the amount of settlement the load produces. If the settlement is so great as to damage the structure, the load is excessive, no matter what may be its relation to the ultimate load the soil will carry. The problem of safe and economical foundation design therefore resolves itself into the problem of distributing the loads on the soil in such a manner that the settlements of the various parts of the structure will not be excessive.

Safe Bearing Value. An assumption very commonly made is that for any given soil there exists a definite safe load intensity. Upon this assumption are based the tables of safe bearing values for soils found in building codes. This method apparently reduces foundation design to a matter of routine. From a scientific standpoint, however, it has many objectionable features. Safe bearing values are not based upon a knowledge of the properties and behavior of soils, but upon the experience obtained in the construction of existing buildings. Their validity is therefore limited to one particular locality, and further limited to structures similar to those extant.

Another limitation is that no account is taken of the manner in which the load is applied. The ratio of the depth of a foundation to its diameter has a marked effect on its settlement under a given load; and it has been shown, theoretically and experimentally, that the diameter of a footing is an important factor. In cohesionless soils, the settlement of a foundation under a given unit load is practically independent of its diameter; while, in soils having high cohesion and low internal friction, the settlement under a given unit load increases directly with the diameter of the loaded area[1].‡

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‡See references at end of paper.

Finally, the method presupposes the possibility of accurate identification of a soil. It is not inconceivable that such identification will eventually be feasible; but at present it consists merely of a vague general description, with no attempt to evaluate the fundamental physical properties of the material.

Loading Tests. In cases where there is felt the necessity of more reliable information than that afforded by tables of safe loads, studies of the load-settlement relation of small areas are often made. Loading tests have a very definite place in soil mechanics and are not to be lightly dismissed. In the absence of other information, however, their results may be very misleading. The effect of the depth-diameter ratio can readily be studied by making the tests in pits. The effect of diameter on settlement is a somewhat more difficult problem. If a one-foot square bearing block is found to settle ¼ inch under a load of three tons per square foot, a raft foundation 100 feet square under the same load may settle ½ inch, or several feet, depending on the character of the soil. This effect may also be studied, at greatly increased expense, by making tests on different areas; but there are cases, one of which will be discussed later, wherein the results of a loading test bear no relation whatsoever to the settlement of the full-size structure.

Computation of Ultimate Bearing Capacity. It may be mentioned in passing that theories have been developed whereby the ultimate bearing capacity of a soil may be computed if its cohesion and its angle of internal friction are known. In the theory of plastic flow,[2] the computation is based on an analysis of the deformations produced by a load applied over an area having a length great in proportion to its width.

Fig. 1 shows a cross-section of a footing resting on the surface of a homogeneous body of soil. In Fig. 1, $q = (c \cot \phi + sb \cot \delta) \left(\frac{1 + \sin \phi}{1 - \sin \phi} e^{\pi \tan \phi} - 1 \right)$, in which q = ultimate load per unit area; c = cohesion of soil; ϕ = angle of internal friction of soil; s = weight of soil per unit volume; b = half width of footing; $\delta = \frac{\pi}{4} - \frac{\phi}{2}$. The soil beneath the footing is divided into three zones. In

zone I the material is compressed and forced bodily downward. In zone II the deformation is a combination of radial shear and rotation. Zone III moves bodily upward and outward.

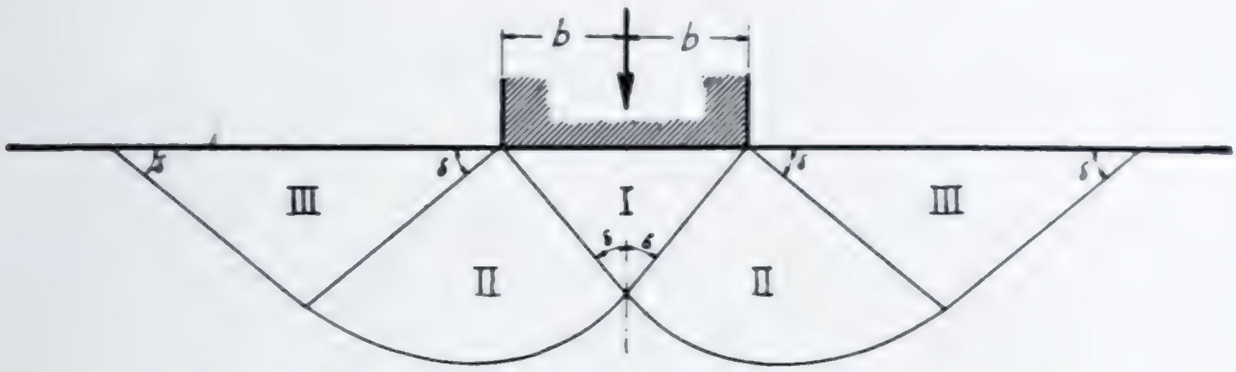

Fig. 1. Theory of Plastic Equilibrium.

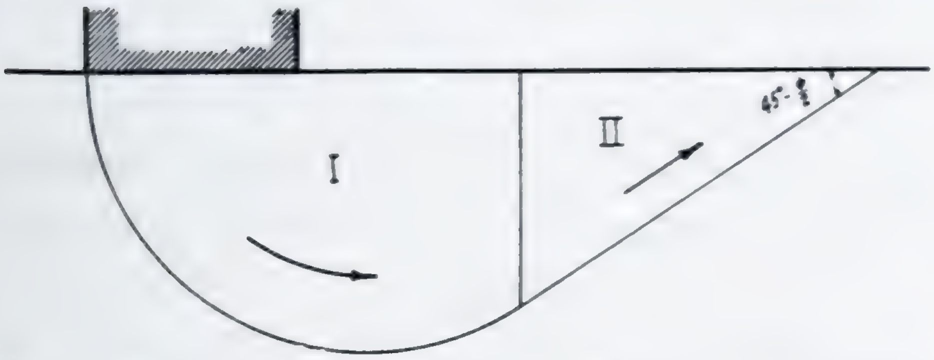

Fig. 2. Failure of a Foundation on Krey's Assumptions.

Fig. 2 shows a similar footing in which the computation is based on Krey's method[3]. For the sake of clearness, the unsymmetrical case is illustrated. The theory is also applicable to symmetrical failures. Zone I is limited by a circle in which the center is arbitrary, and zone II by a tangent to this circle making an angle of 45 degrees — $\frac{\phi}{2}$ with the surface. Zone I is considered to rotate about its center, and zone II to move upward and outward along the tangent, movement being resisted by the shearing strength of the soil along the interfaces. The cohesion and friction being known, it is possible to find by trial a circle which will give a minimum value of the load. The computations can be best handled graphically, and are comparatively simple. The results agree fairly well with those of the more accurate theory of plastic flow.

These theories are valuable in the study of extreme loading conditions, but they fail to provide means of solving the all-important problem of settlements.

Stress Distribution under Loaded Areas. In the solution of problems involving the deformation of a material under stress, the logical procedure is, first, to analyze the stresses in the material, and next, to evaluate the effects of these stresses in terms of deformation. Analysis of the stresses under a foundation is a far more complex affair than a similar analysis of a truss. Methods are at hand, however, whereby such an analysis can be made, at least for simple cases.

In 1885 Boussinesq[4] published a mathematical treatment of the problem of the stresses set up in a homogeneous mass of infinite extent by a load applied at a point on its surface, and obtained equations for the normal and shearing stresses at any point, P, in the mass. The equations were somewhat complicated and, therefore, of very limited practical value. It was later shown,[5] however, that the four stresses determined by Boussinesq were very nearly equivalent to a single stress directed along the radius joining the point P with the point of load application. If the length of this radius is r, and the angle it makes with the vertical is ψ, then the stress intensity, p_r, in the direction of the radius due to a load Q on the surface is

$$p_r = \frac{3}{2} \frac{Q}{\pi} \frac{\cos \psi}{r^2} \quad \text{..............................} (1)$$

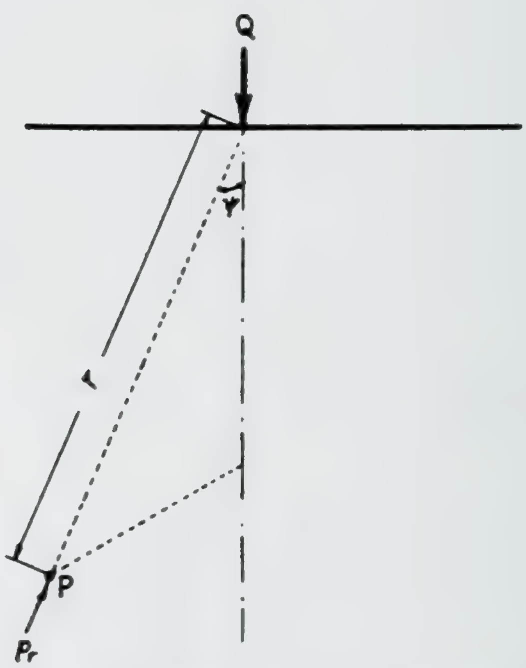

Fig. 3. Stress at Any Point in a Soil Mass Due to Point Load on Surface.

The quantities are represented diagrammatically in Fig. 3.

If, instead of a concentrated load Q at a point, the stress is due to a load q per unit area distributed over a surface S, then the stress

conditions at the point P are determined by the general surface integral

$$\frac{3q}{2\pi}\int \frac{\cos\psi}{r^2}\,dx\,dy \qquad (2)$$

In the evaluation of this integral, account must be taken of the fact that the direction of p_r is different for different positions of the elementary area $dx\,dy$.

The integral has been evaluated[6] for a long footing; that is, one having a length so great in proportion to its breadth that its length may be considered infinite. An approximate solution is possible for any shape by dividing the loaded area into small squares, or rectangles which are nearly square, and considering the load on each element to be applied at a point. It has been found by trial that the error of this method is small, provided the longest side of the elementary rectangle is shorter than one-third of the depth to the level at which the stress is being investigated.

By this method the pressure distribution on any horizontal plane in a homogeneous soil mass loaded in any manner can be computed with considerable accuracy. From equation (1) it is evident that the vertical component of stress p_v at point P is

$$p_v = \frac{3}{2}\,\frac{Q}{\pi}\,\frac{\cos^3\psi}{r^2} \qquad (3)$$

Suppose that it is desired to compute the total intensity of vertical stress at a point P_1, located at a distance z_1 below the bottom of a foundation slab. Consider the slab to be divided into rectangles with sides a and b, where a and b may be constant or not, according to convenience; that is, all rectangles may be of the same size, or they may differ in size, the essential requirements being that a and b are of the same order of magnitude (say a not less than $\frac{b}{2}$ and not greater than $2b$), and that neither a nor b is anywhere greater than $\frac{z_1}{3}$. Let the intensity of load on any square be q; q may be constant over the whole slab, or may vary from point to point. The total load on any square is qab.

Place the origin of the rectangular co-ordinate system at the point P_1 with the Z axis vertical, and the X and Y axes in such a

position as to make computation easy; for a rectangular slab, they would naturally be placed parallel to the edges. Let x, y, z_1 be the co-ordinates of the central point of any one of the elementary rectangles. A typical case is illustrated in Fig. 4.

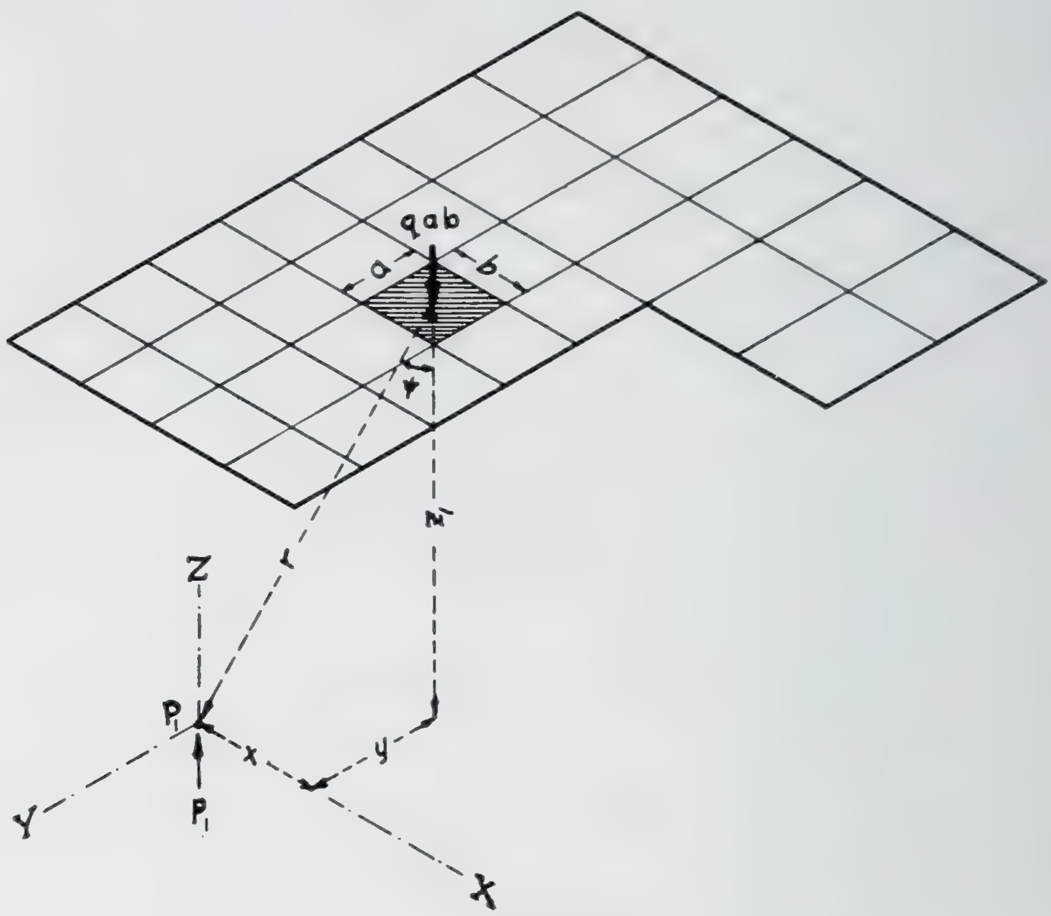

Fig. 4. Vertical Stress at Any Point in a Soil Mass Due to Distributed Load on Surface.

From the geometrical relations, $r^2 = x^2 + y^2 + z_1^2$, and $\cos^3 \psi = \left(\frac{z_1}{\sqrt{x^2 + y^2 + z_1^2}}\right)^3$. Hence, from equation (3), the vertical stress intensity at p_1 due to the load on any one of the rectangles is

$$\frac{3}{2}\frac{qab}{\pi}\frac{z_1^3}{(x^2 + y^2 + z_1^2)^{\frac{5}{2}}} \text{.....................} (4)$$

One such term must be computed for each rectangle. Then the total stress intensity, p_1, at the point in question will obviously be the sum of all these terms. Symbolically,

$$p_1 = \frac{3}{2\pi}\,\Sigma\,\frac{qabz_1^3}{(x^2 + y^2 + z_1^2)^{\frac{5}{2}}} \text{.................} (5)$$

If P_2, P_3, etc., are other points on the same level as P_1, the same computation can be performed for each point, resulting in values p_2, p_3, etc., for the stresses. The ordinates p_1, p_2, p_3, etc., define a surface which represents graphically the stress distribution over the level in question.

As a simple illustration, let it be required to compute the stress distribution on a level 60 feet below the bottom of a slab 30 by 40 feet, loaded with a uniform load of three tons per square foot. The slab can be divided into four equal rectangles, 15 by 20 feet, which will fulfil the conditions previously imposed. The load is thus re-

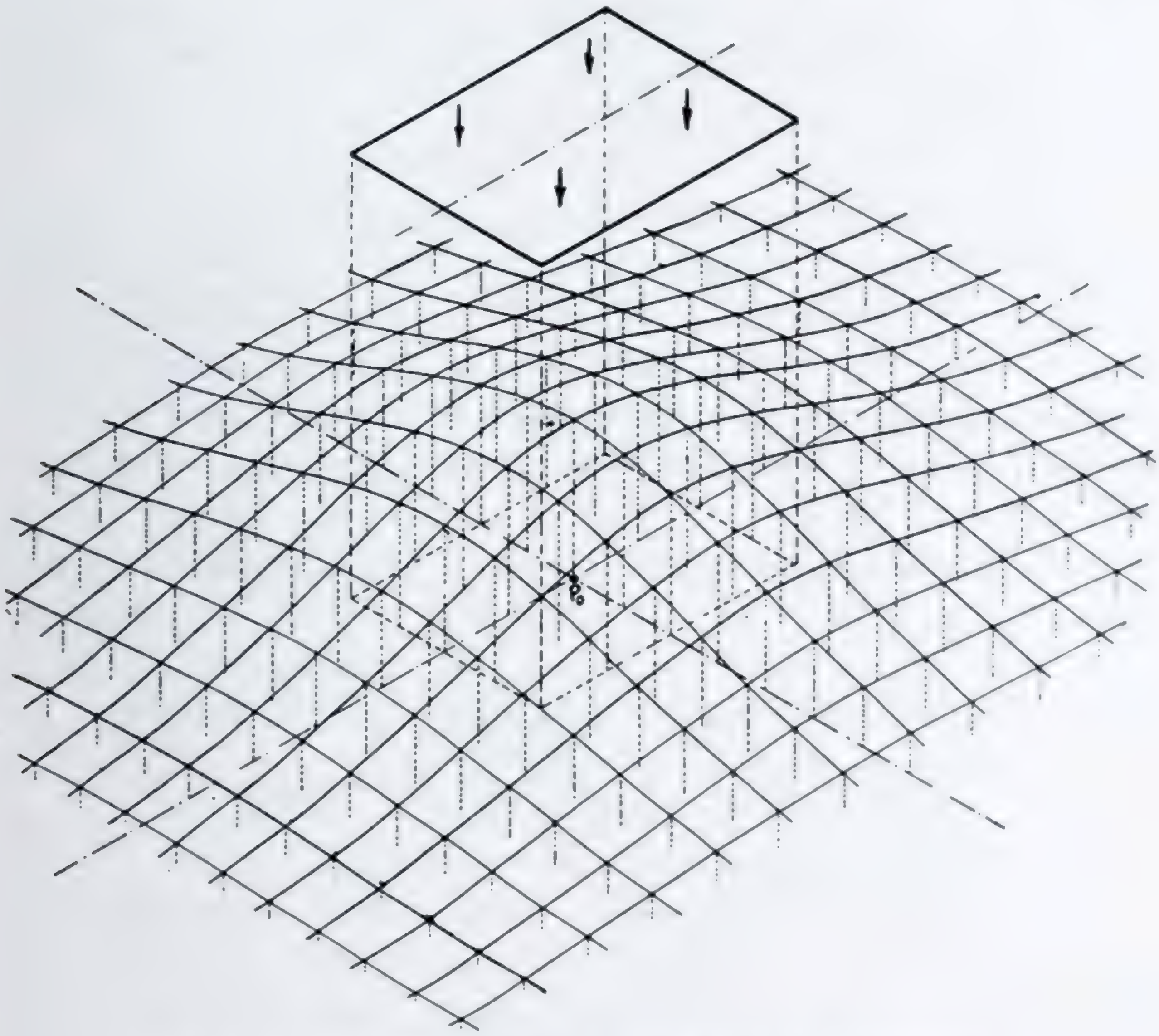

Fig. 5. Typical Diagram of Stress below a Foundation.

duced to four point loads of 900 tons situated as shown in Fig. 5. Consider first a point, P_0, on the given level directly under the center of the slab. Let the X axis be parallel to the long side of the slab. Since the loading is symmetrical about the Z axis, the total stress at P_0 will be four times that due to one of the loads. For any one of

the loads, $x = 10$ feet, $y = 7.5$ feet, $z_1 = 60$ feet; hence the total stress intensity, p_0, is given by

$$p_0 = 4 \times \frac{3}{2\pi} \times 900 \times \frac{60^3}{(10^2 + 7.5^2 + 60^2)^{\frac{5}{2}}} = 0.43 \text{ ton per}$$

square foot.

In a similar manner, the origin of co-ordinates is moved successively to other points on the 60-foot level, and the corresponding computation made. The final result is a complete representation of the stress distribution on the level in question, indicated diagrammatically in Fig. 5. It is true that the computations are somewhat tedious and may occupy considerable time; but the essential fact is that the method exists and can be utilized to advantage whenever accurate information is desirable.

Compressibility of Soils. The next step is the investigation of the deformations and consequent settlements produced in the soil by the computed stresses. From a general standpoint, this phase of the problem is not simple, inasmuch as settlement may be due both to lateral displacement and to compression of the material. The present analysis will be limited to those cases in which volumetric change is the principal factor.

A soil mass consists of a continuous network or skeleton of solid grains, the voids in the network being filled with air, with water, or partly with air and partly with water. The decrease in volume of such a mass under pressure can be due only to three factors:

1. Compression of the solid matter.
2. Compression of the liquid in the voids.
3. A decrease in the volume of the voids.

Under the pressures ordinarily encountered in foundation work, the first two effects are negligible, the solid grains and the water being relatively incompressible; hence the decrease in volume of the mass may be considered to be entirely due to a decrease in its volume of voids.

If a sample of dry sand is placed in a shallow steel ring resting on the bed of a testing machine, and a load applied through a block slightly smaller in diameter than the ring, the sand will be compressed; that is, its volume of voids will be decreased. This is the same as saying that a certain amount of air is forced out of the

sample. Since there is practically no resistance to the escape of the air, compression will occur almost instantaneously. If the soil is saturated, the compression involves forcing out a certain amount of water. The resistance of sand to the passage of water is relatively low, so that again the compression is practically instantaneous.

If a similar test is made on a sample of saturated clay, the effects are similar in principle, but widely different in detail. In the first place, the decrease in volume of the clay is many times greater than that of the sand under the same pressure. Furthermore, the permeability of the clay is so low that the water can not be forced out instantaneously; the compression proceeds slowly, and it may be a day, a week, or a month, depending on the nature of the material and the size of the sample, before the change in volume is completed.

Between the relatively incompressible, relatively permeable sand, and the highly compressible, impermeable clay, there is an infinite variety of materials exhibiting infinite variations in behavior under pressure. The only satisfactory method of evaluating the compressibility of any given soil is by means of actual tests.

From an experimental standpoint, studies of sands are comparatively simple. For fine-grained, compressible soils the apparatus shown in half section and half elevation in Fig. 6 has been developed. The soil sample, initially in a saturated, liquid condition, is held in a cyl-

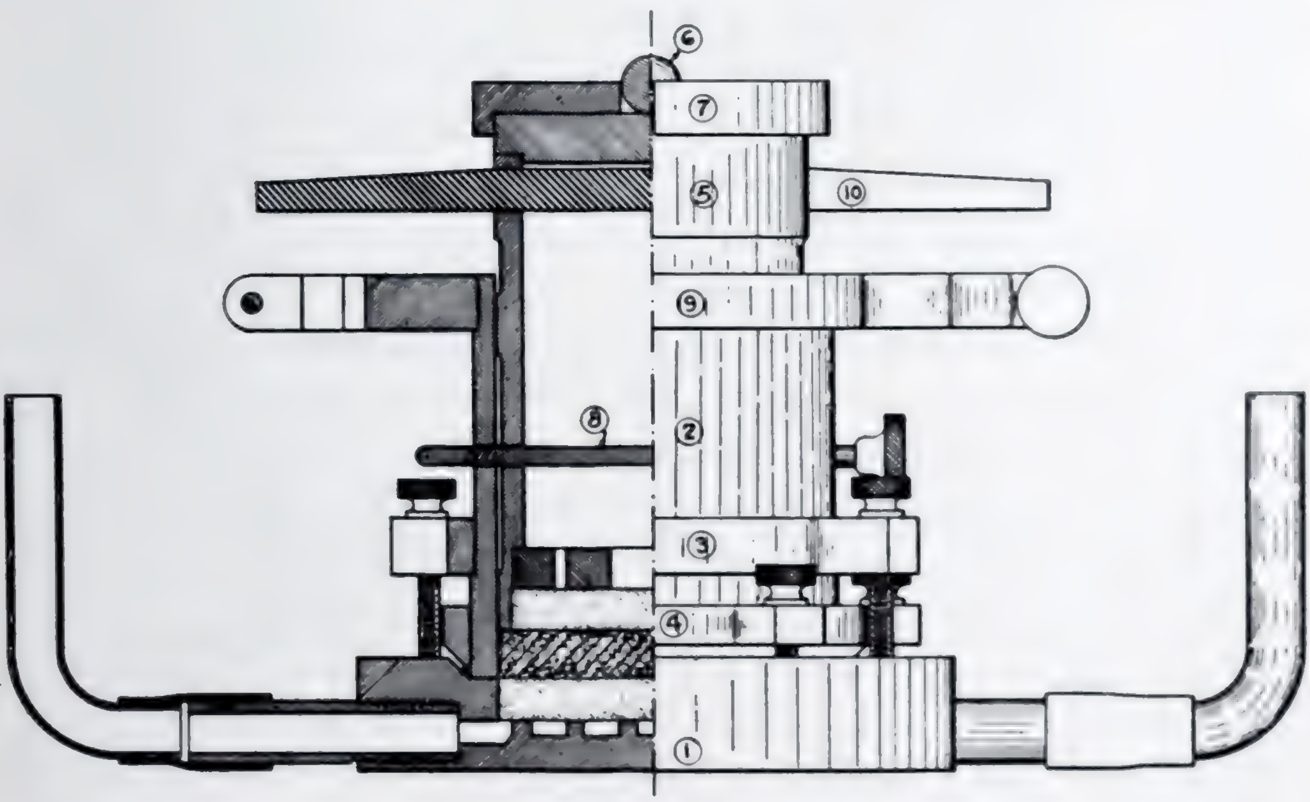

Fig. 6. Consolidation Apparatus.

inder (2), 2¾ inches in diameter, between two porous disks. The lower disk sets in the base (1), free water passage being provided by channels below the disk communicating with glass stand-pipes which are open to the atmosphere. The upper disk is set in the end of a hollow piston (5), the supporting plate being perforated to permit free passage of water between the disk and the interior of the piston. A stop pin (8) is provided for holding the piston and the cylinder together while the sample is being introduced. When the test starts, the pin is removed, allowing the piston to slide freely within the cylinder. During the test the interior of the piston and the base stand-pipes are kept filled with water to the level of the pinholes, so that the entire operation proceeds under water.

Load is applied to the top of the piston and transmitted by it directly to the soil. The compression of the soil sample is measured to the nearest hundred-thousandth of an inch by means of two Ames dials (not shown) carried on a dial ring (9) with their plungers bearing against a beam (10) integral with the piston.

By applying various loads to the soil, and noting the dial readings as time goes on, a complete representation of the pressure-compression and time-compression characteristics of the soil may be obtained. To make the results readily applicable, the compression is expressed not as inches or centimeters, but as a change in voids ratio (ratio of volume of voids to volume of solid). The results of a typical standard test are shown in Fig. 7 and 8. Fig. 7 shows the pressure and voids ratio diagram obtained by applying a total load of 3.2 kilograms per square centimeter in four increments and then removing it in the same increments. Each increment of load is allowed to act until no further dial movement occurs; that is, until the compression due to that particular increment has proceeded to completion. During the progress of the compression under constant load, dial readings and time readings are recorded. The total compression produced by the increment of load is taken as 100 per cent., and the intermediate dial readings are plotted on this basis against time, giving a time-compression curve of characteristic shape as shown in Fig. 8. The results of this test thus make it possible to determine with considerable accuracy not only the compression which will be produced by a given increase of load, but also the rate at which the compression will proceed.

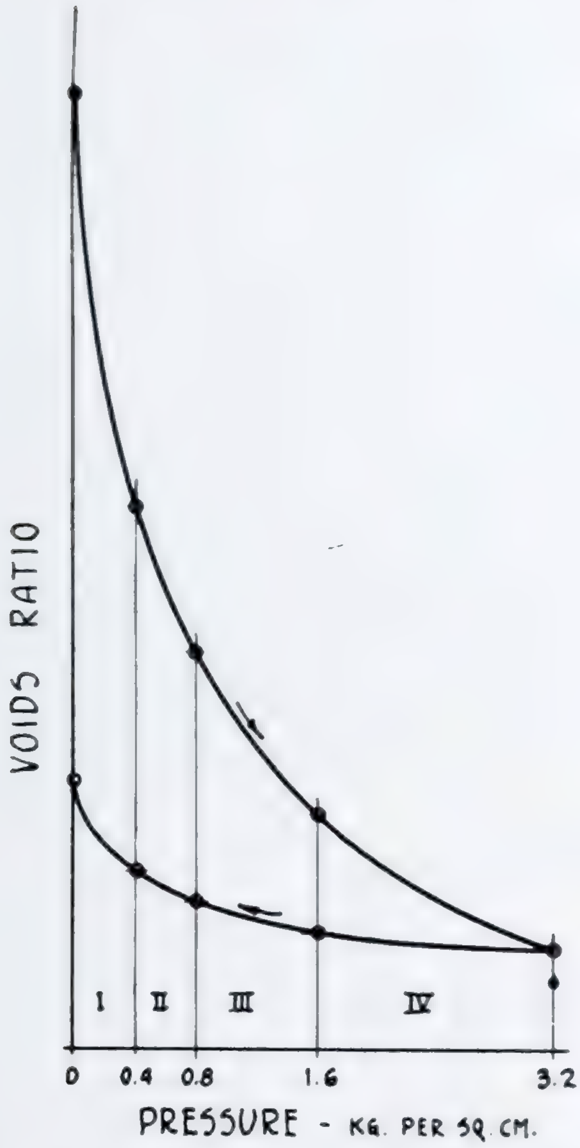

Fig. 7. Typical Results of a Consolidation Test.

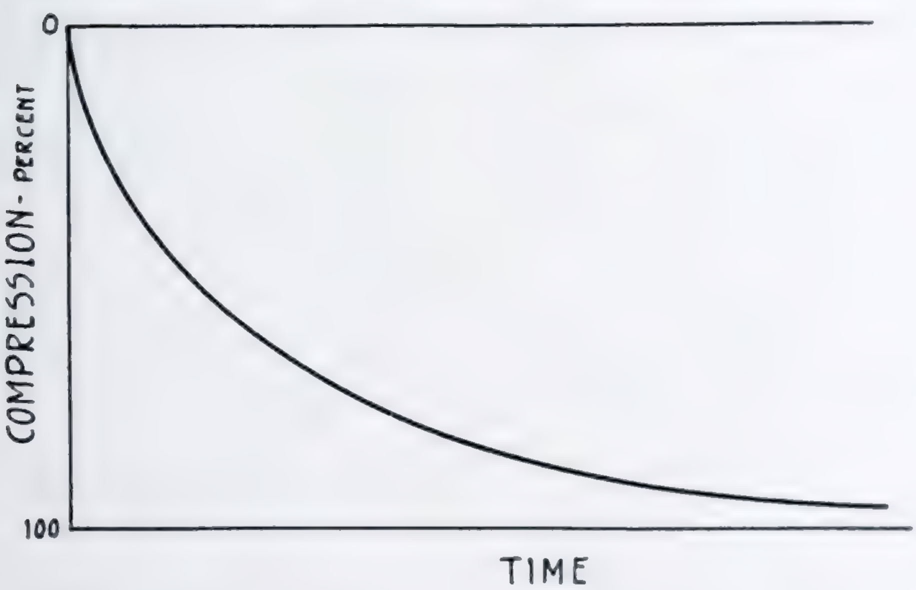

Fig. 8. Typical Results of a Consolidation Test.

Simplest Case. Consider the 30- by 40-foot raft combination previously mentioned, designed to apply a pressure of three tons per square foot to the soil. Assume that it rests on a more or less homo-

geneous deposit of dense sand and gravel. Thirty feet below the raft is the upper surface of a clay deposit 10 feet thick. Below this to an indefinite depth is more sand and gravel. Ground water is 10 feet below the raft. Assume the sand and gravel to weigh 110 pounds per cubic foot dry, and 70 pounds per cubic foot submerged. Then the pressure of the overburden on the clay will be $10 \times 110 + 20 \times 70 = 2500$ pounds per square foot $= 1.25$ tons per square foot.

The stresses on the surface of the clay can be computed in the same manner as previously illustrated for the 60-foot level, except that it will be necessary to divide the raft into 12 squares each 10 feet on a side, corresponding to 12 point loads of 300 tons each. The division of the slab and the computation of the stress at a point on

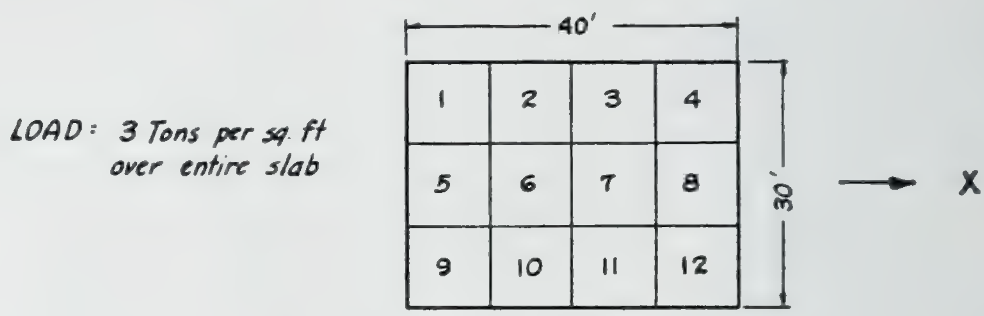

Fig. 9. Stress Computation.

the surface of the clay directly under the center of the slab are shown in Fig. 9 and Table I. From Table I and equation (5), the stress is $\frac{3}{2\pi} \times 300 \times 30^3 \times 31.90 \times 10^{-8} = 1.23$ tons per square foot. In a complete analysis, other points would be computed in the same manner. The pressure at the point computed, 1.23 tons per square foot, is the maximum existing on the clay layer.

Assume that borings have been made and samples of the clay extracted. The Boston building code gives as a safe bearing value for "medium stiff or plastic clay" four tons per square foot, and for "soft clay protected against lateral displacement" two tons per square foot. The material which will be considered later would probably fall into the former classification; but, even if it were termed "soft," the actual maximum stress is well within the allowable limit. By the same code, compact sand and gravel can be loaded to six tons per square foot; so that, according to the regulations, the slab as designed should be more than safe.

TABLE 1. COMPUTATION OF STRESS AT POINT P_0, 30 FEET BELOW CENTER OF SLAB

Square	x	y	x^2	y^2	$x^2+y^2+z^2$	$(x^2+y^2+z_1^2)^{-\frac{5}{2}}$
1	15	10	225	100	1225	1.90×10^{-8}
2	5	10	25	100	1025	2.98
3	5	10	25	100	1025	2.98
4	15	10	225	100	1225	1.90
5	15	0	225	0	1125	2.35
6	5	0	25	0	925	3.84
7	5	0	25	0	925	3.84
8	15	0	225	0	1125	2.35
9	15	10	225	100	1225	1.90
10	5	10	25	100	1025	2.98
11	5	10	25	100	1025	2.98
12	15	10	225	100	1225	1.90
					Total	31.90×10^{-8}

The results of loading tests on the soil would undoubtedly be very reassuring. Compact sand and gravel is a very incompressible material. A rough computation will show that as far as loading tests of any reasonable size are concerned, the clay layer is practically non-existent. If a load 100 per cent. greater than that contemplated is tested on an area of four square feet, the maximum stress on the clay would have the negligible value of $4 \times 6 \times \frac{3}{2} \times \frac{1}{(30)^2} = 0.0127$ ton per square foot.

Under three tons per square foot, the loading test might show a settlement of the bearing block of, say, ⅛ inch. The soil is cohesionless, therefore the settlement under a given unit load is practically independent of the area. The designer might proportion the other members of the structure so that a settlement of the raft of ¼ inch, or (being very conservative) of ½ inch, would not cause serious stresses. He might then consider the problem solved.

Now suppose that the clay samples are brought into the laboratory and tested for compressibility. An average of the results might be as represented in Fig. 10. (The values used herein have been taken from a test performed at Massachusetts Institute of Technology on a sample of clay from the Mississippi Valley.) At (*a*) is shown the pressure and voids ratio relation. From this curve it can be seen that under the load to be applied the voids ratio of the clay under the center of the raft will eventually decrease from 1.335 to 1.150. From the results of time observations, a curve of percentage compression against time in minutes is constructed, as shown at (*b*).

To apply the test results to the actual case, it is necessary to introduce the "reduced thickness," which is defined as the thickness the layer would have if all the solid material could be concentrated down to a condition of zero voids. The reduced thickness is the true thickness divided by 1 plus the voids ratio. The reduced thickness of the 10-foot layer with a voids ratio of 1.335 is evidently $10 \div 2.335$, or 4.28 feet. Then the true thickness of the same layer at a voids ratio of 1.150 would be 4.28×2.150, or 9.2 feet; hence the total settlement under the center of the slab will be 0.8 foot, or 9.6 inches. Using this value as 100 per cent., the auxiliary vertical scale of settlement in inches is laid off on (*b*).

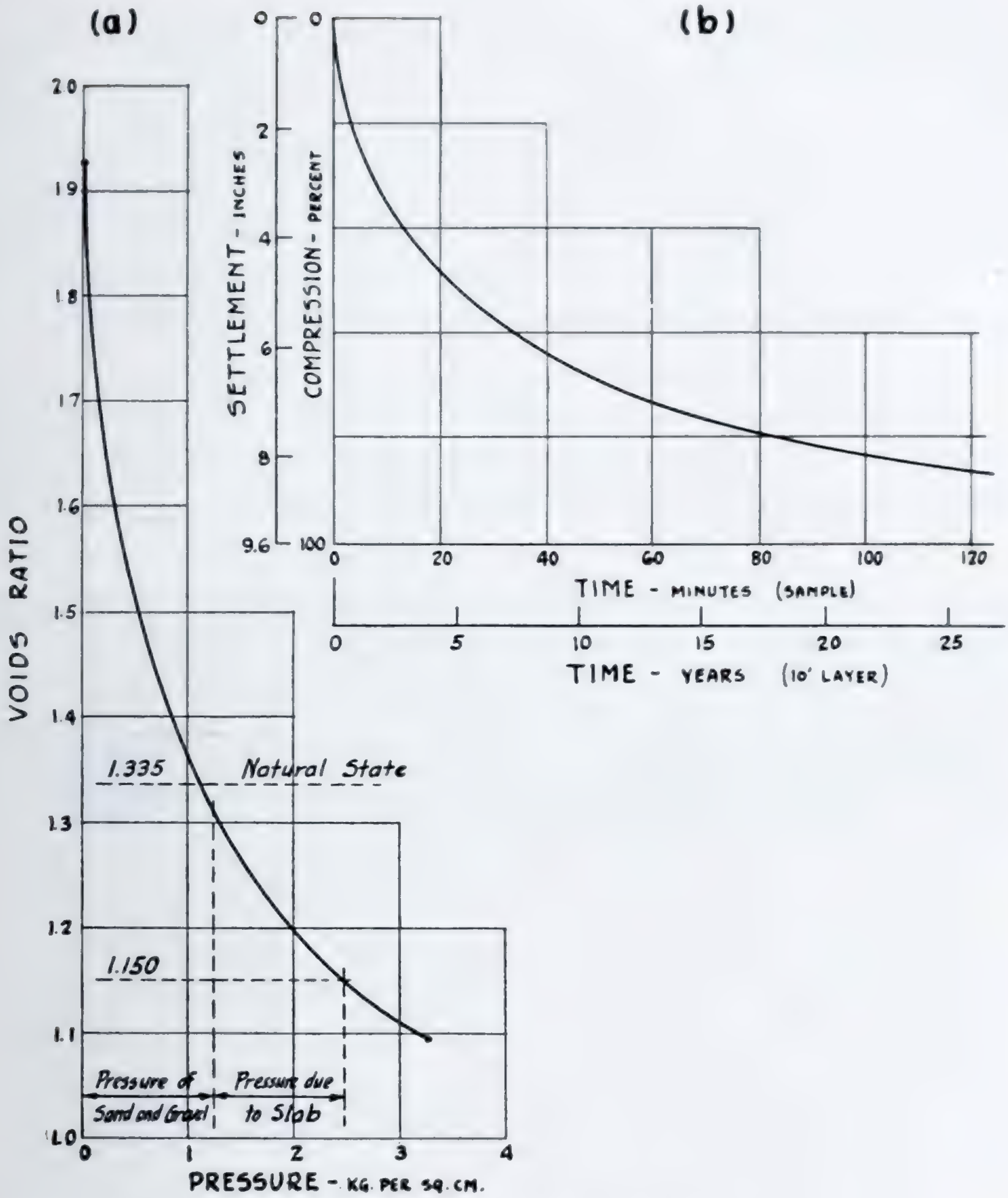

Fig. 10. Settlement Diagrams.

The theory of the consolidation process[7] shows that the rates of compression of two layers of the same material under the same pressure conditions are inversely proportional to the squares of the reduced thicknesses of the layers. The reduced thickness of the sample in the test was 0.386 centimeter, or 0.0127 foot; hence one hour in the test corresponds in the 10-foot layer to $\frac{(4.28)^2}{(0.012)^2} = 114{,}000$ hours, or 12.9 years. It is thus possible to construct the auxiliary horizontal scale of time in years for the 10-foot layer, as shown at (*b*) in Fig. 10.

Further comment on the diagram is hardly necessary. Due to the slow rate at which consolidation proceeds, the settlements observed during construction would probably be comparatively small; but they would continue as time went on, and in a relatively short span of years would amount to several inches. The safe bearing value, the results of the loading tests, and the assumed allowable settlement of ¼ or ½ inch would be quite meaningless.

An Actual Case. The conditions assumed in the foregoing illustration are admittedly of the type which most easily yield to analysis. The occurrence of similar cases, however, is not at all uncommon.

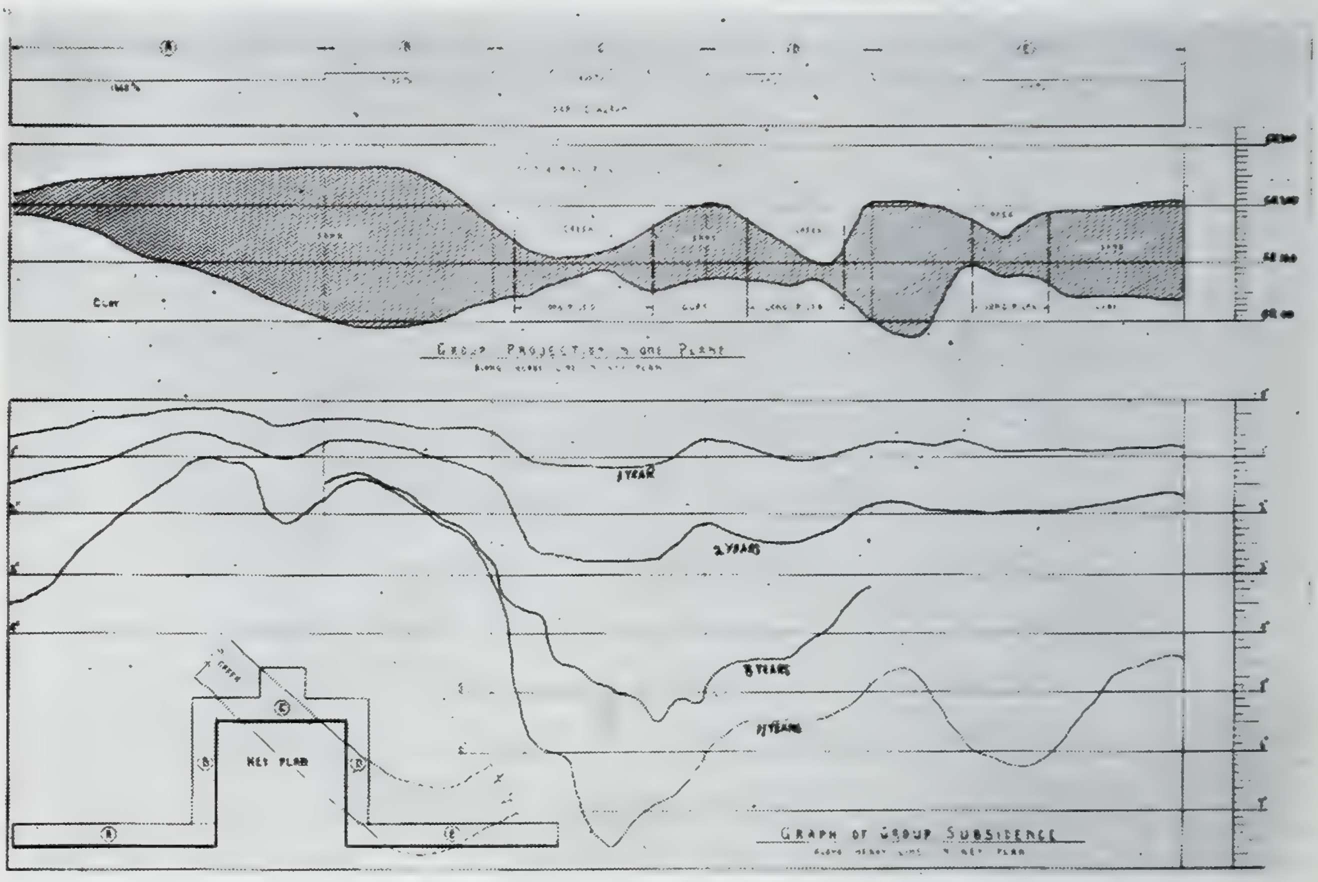

Fig. 11. Settlements of Existing Building Due to Slow Consolidation of Clay Layer.

One very striking example is shown in Fig. 11. When a group of buildings was designed, it was considered of utmost importance to have a first-class foundation. The foundation was designed to conform to the following criteria:

1. The maximum allowable settlement to be ¼ inch.
2. A settlement of ½ inch, or over, to be considered failure.

Elaborate loading tests were carried out on piles of various materials, sizes, shapes, and lengths, and from the results the piling was proportioned so that the specifications would be fulfilled.

During construction, all went well, but the succeeding years told a different story. At the end of 11 years, the maximum settlement was 7½ inches; the minimum one inch—a differential settlement of 6½ inches. The central section was slightly heavier than the others, and at this point the sand layer was thin. As an added measure of safety, this section was supported on long piles driven deep into the clay. Here the maximum settlement was observed; not so much on account of the greater load as on account of the fact that the load was transmitted directly to the clay by the piles, consequently speeding up the consolidation process. The same effect can be seen at other points where the piles throw the load directly into the clay.

The designers of this project are not to be censured. They took all possible care and every known precaution to insure a first-class piece of work. The unsatisfactory results were due to the fact that they did not have at their disposal any information regarding the mechanics of soils which would afford a basis for predicting the behavior of the structure.

Conclusion. This discussion is not intended to convey the impression that foundation problems are relatively simple. Long-continued theoretical and experimental studies will have to be pursued before the complexities of soils are understood. An essential element in these studies is the recording and analysis of observations on the settlements of existing buildings. The required data include:

1. A load-progress diagram.

2. Level readings on a number of points of the structure at various times during and after construction.

3. A geological profile of the underground.

4. A few tests on the physical properties of the soil in different strata.

The accumulation of such data could readily be made part of every important piece of work without adding appreciably to the cost of construction. If information of this type were available from a great number of sources, it would immeasurably increase the rate of

progress toward the ultimate goal of safe, sound, and economical foundation design.

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OPEN-HEARTH COMBUSTION*

By W. P. Chandler, Jr.†

The maintenance of proper combustion in an open-hearth steel furnace is not greatly different from that for any combustion unit. However, the high temperature at which the bath must be maintained and the effect of direct contact of the products of combustion on the brickwork or the materials in the bath produce conditions requiring careful study if a maximum economical use is to be made of the fuel fired. It will be recalled, for instance, that Siemens in his original development of the open-hearth steel furnace using producer gas as fuel, was unsuccessful in his attempts until he preheated the air and thus obtained the high flame temperature necessary for his process. Somewhat later Prof. H. H. Campbell in his "Manufacture and Properties of Structural Steel"‡ made the statement that the problem in an open-hearth furnace was not to reach the desired temperature but to control the temperature and prevent the roof and walls from melting down.

The present paper will endeavor to point out the various factors concerning combustion which have to be considered if proper economical operation of a furnace is to be obtained. The heat requirements of the process, the relative value of the fuels to be used, the various methods which may be employed to insure maximum conditions, and the proper port and furnace design which will guard against serious damage to refractories or materials in the bath, must all be given due weight in any study of open-hearth combustion.

Heat Requirements. The term heat requirement as applied to an open-hearth furnace is an indefinite quantity. Different companies report heat consumption per ton of ingots produced varying from 3,500,000 to 7,500,000 B.t.u., so it is apparent that local conditions of design, operation and accounting have enormous bearing on the requirement.

A very careful analysis of the heat requirements of an open-hearth furnace is given by Mr. Waldemar Dyrssen in discussion of a paper by Kinney and McDermott in the 1922 *Year Book of the*

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‡1896. Scientific Publishing Co., New York.

American Iron and Steel Institute (p. 464). The analysis covers the operation of a producer-gas-fired furnace producing 80 gross tons of ingots per heat and using 60 per cent. of the metallic charge in the form of hot pig-iron. It is shown that the net heat requirement of the bath, including the sensible heat added plus that required for chemical reactions minus that produced by chemical reactions, amounts to 230,000 B.t.u. per gross tons of ingots. This value, less than one-quarter of a million B.t.u. per ton, is the heat requirement of the process as far as the metallurgical demands are concerned. Under such conditions the fuel efficiency of the furnace—that is, the efficiency based on the heat absorbed from the producer gas—divided by the heat supplied to the furnace by the producer gas is four per cent. While this value is the true fuel efficiency of the furnace, the usual efficiency for open-hearth furnaces is the 20.9 per cent. shown by Mr. Dyrssen as the gross efficiency. This is based on the heat required in the bath for sensible heat and chemical reactions divided by the heat in the producer gas to the furnace, plus the heat generated by the oxidation processes in the bath.

A heat balance based on the above data for the melting chamber and port ends is given in Table I.

TABLE I. HEAT BALANCE FOR HEARTH OF 80-TON FURNACE

	Million B.t.u. per heat	Per cent.
Producer gas to melting chamber	465.0	65.7
Air to melting chamber	149.2	21.1
Heat from chemical reactions in charge	93.4	13.2
Total heat input	707.6	100.0
Sensible heat added to charge	82.9	11.7
Heat required for chemical reactions in bath	28.9	4.1
Heat radiated from melting chamber and port ends	63.9	9.0
Heat to cooling water in melting chamber and port ends	70.6	10.0
Heat in waste gases from chamber	461.3	65.2
Total heat output	707.6	100.0

It will be noted that the heat actually required metallurgically consists of the sensible heat added to the charge and the heat required for chemical reactions, and amounts to 11.7 per cent. plus 4.1 per

cent., or 15.8 per cent. As a partial source of this heat requirement there is generated in the bath by chemical action (principally oxidation) 13.2 per cent., leaving 2.6 per cent. of the total heat to be supplied by the fuel. With an actual heat requirement of such a small amount, the reduction of the losses becomes of the utmost importance.

With a sharp-working furnace, the waste gases leaving the furnace must be maintained close to 3000 degrees F. and any reduction in this temperature means a slowing up of the operation. For a given fuel the only method available for reducing the loss through waste gases is a reduction in the amount of waste gases by maintaining combustion at as nearly theoretical proportions as possible. The fuel having the smallest amount of waste gas per heat unit developed will produce the lowest loss through waste gas.

The radiation and water-cooling losses for a given furnace are a constant quantity per hour, so any reduction in time of heat reduces these losses per ton of ingots produced. The reduction in time of heat is normally accomplished by an increase in the rate of heat transfer from the fuel to the bath due to the maintenance of a higher combustion temperature. Such an increase in combustion temperature is dependent on the fuel used, the degree of preheat, the quantity of air used for combustion, and the design of the port or burner. The influence of these various factors will be discussed later.

Fuels. The selection of the fuel to be used in any individual open-hearth plant, while primarily an economic one, becomes usually one of availability. The Pittsburgh territory developed as a steel-producing center mainly with the aid of the natural gas present in the district. Along the Atlantic seaboard and in the Chicago district, the choice between fuel-oil and producer gas changed back and forth with the market price of coal and oil delivered at the plant. In recent years the development of the by-product coke industry has produced supplies of coke-oven gas and tar which are wholly or partly consumed by the open-hearth furnaces operated in proximity to the ovens. The use of blast-furnace gas mixed in various proportions with coke-oven gas will probably find a wide application in the next few years.

Of the various fuels which may be applied to open-hearth furnaces, certain physical and chemical properties of each must receive

due consideration, if the application is to be wholly successful. Table II has been prepared to indicate a comparison of the chemical analysis and combustion requirements of the various fuels normally met with in open-hearth furnace practice.

TABLE II. COMPOSITION OF FUELS

	Natural gas	Coke-oven gas	Producer gas—Rich	Producer gas—Lean	1/3 coke oven 2/3 blast furnace	Coke-oven tar	Fuel oil
Analysis by volume: % CO_2	0.2	1.5	4.5	6.83	9.2		
C_2H_4	0.4			0.43			
Illuminants		3.4	0.5		1.1		
CO		5.9	25.8	21.74	19.2		
CH_4	77.7	29.7	2.8	3.60	9.9		
C_2H_6	19.4	1.1			0.4		
H_2		57.0	12.6	12.77	21.5		
N_2	2.3	0.7	53.8	54.63	38.5		
H_2S		0.7			0.2		
Heat value (B.t.u. cu. ft. or gal.)							
Net	1030	528	152	144	238	150,300	138,500
Gross	1138	592	161	155	260	155,300	146,600
Weight lb. 1 cu. ft. or gal.	0.05079	0.02679	0.06648	0.06711	0.06028	9.5	7.7
Analysis by weight: % C	73.7	56.3	16.4	15.6	22.0	86.7	84.6
H_2	22.6	25.5	1.5	1.7	4.0	6.0	10.9
O_2	0.3	14.1	22.2	22.3	26.4	3.1	2.9
N_2	3.4	1.9	59.9	60.4	47.3	0.1	
S		2.2			0.3	0.8	1.6
H_2O						3.2	
Heat value (B.t.u. 1 lb.)							
Net	20,280	19,684	2,279	2,138	3,950	15,827	17,991
Gross	22,400	22,076	2,425	2,293	4,329	16,341	19,026
Theoretical air requirements							
Cu. ft. per cu. ft. or gal. fuel	10.74	5.15	1.27	1.23	2.19	1490	1360
Lb. per cu. ft. or gal. fuel	0.8230	0.3955	0.0952	0.0945	0.1676	114.0	104.0
Lb. per lb. of fuel	16.20	14.78	1.44	1.41	2.78	12.0	13.5
Lb. per million net B.t.u.	798	748	625	657	704	758	752
Products of theoretical combustion							
Analysis by volume: CO_2	10.0	8.1	16.5	16.0	14.0	16.0	13.7
H_2O	18.1	21.9	9.3	10.1	15.1	10.7	13.9
N_2	71.9	69.9	74.2	73.9	70.7	73.2	72.3
SO_2	0	0.1	0	0	0.2	0.1	0.1
Lb. per cu. ft. (products)	0.738	0.0724	0.0778	0.0786	0.0762	0.0781	0.0765
Cu. ft. per cu. ft. or gal. fuel	11.837	5.842	2.079	2.058	2.988	1618	1490
Lb. per cu. ft. or gal. fuel	0.8738	0.4223	0.1617	0.1616	0.2279	126.1	114.0
Lb. per lb. of fuel	17.20	15.78	2.44	2.41	3.78	13.30	14.8
Lb. per million net B.t.u.	847	799	1063	1123	957	838	823

In addition to the chemical analysis which fixes the heating value of the various fuels, certain physical qualities greatly affect the character of the flame produced in the furnace. During the melting down period of the heat a short, sharp flame results in the fastest working furnace; but, from the time the heat is under cover, a reasonably long luminous flame passing close to the surface of the bath produces the best results.

Liquid Fuels. In the case of the liquid fuels, such as oil or tar, a luminous flame is characteristic, while the position of the flame in the furnace is readily controlled by the pressure of the atomizing medium and the position of the burner, since the force of the moving stream of atomized fuel is sufficient to determine the flame.

Producer Gas. Producer gas carries small particles of carbon as dust in suspension out of the producer, and in passing through the gas checker it is still further enriched in carbon particles by the cracking of some of the hydrocarbon constituents of the gas. As a result of the carbon particles carried by the gas, a producer-gas flame is luminous.

By referring to Table II it will be noted that 1.4 pounds of air per pound of gas are required for perfect combustion. Due to the fact that the weights of air and gas are nearly the same it is relatively easy to design a gas port which will give the gas stream such velocity and direction that it can impart the necessary force to the air stream required to produce the desired flame in the furnace. The important factor to be considered in a gas port is the ability to maintain the port lines throughout the life of the furnace.

Mixed Blast-Furnace and Coke-Oven Gas. In the case of a fuel consisting of a mixture of blast-furnace and coke-oven gases, a condition exists which is somewhat analogous to producer gas as far as direction and position of the flame in the furnace are concerned, the velocity and weight of the gas stream being sufficient to determine the position of the flame in the furnace. The production of a luminous flame can be accomplished by improper mixing of air and gas and a deficiency of air supply, but such procedure results in a lowering of the flame temperature and a slowing up of the furnace. A more feasible means of producing a luminous flame has been developed as

the result of recent experiments made abroad, particularly in Germany. These experiments conducted with a mixture of blast-furnace and coke-oven gas have shown that with sufficient preheat the hydrocarbons can be dissociated so as to produce enough carbon particles in the form of soot to give luminosity to the flame. The old theory maintained that the cracking of hydrocarbons in checker chambers would result in depositing soot and clogging the chambers. Actual experience has shown that the soot or carbon particles are not deposited, but pass along with the gas stream into the furnace. The experiments indicate that a relatively high preheat for the mixed gas (2200 degrees F. or over) is required if the proper cracking of hydrocarbons is to be accomplished.

Coke-Oven Gas. By reference to Table II it will be noted that nearly fifteen pounds of air are required to burn one pound of coke-oven gas. For this reason it has been found impossible to give direction or position to the flame in the furnace by any manipulation of the gas-burner alone. Practice has shown that the design of the air port is the main factor in obtaining the desired position of the flame in the furnace. Under such conditions the gas-burner becomes a means for properly bleeding the coke-oven gas into the air stream so as to obtain intimate mixture and quick ignition, without damage to the roof of the incoming port. With such construction, it is possible to produce a very sharp cutting flame which results in rapid melting. The inability of this method to produce a luminous flame in close proximity to the surface of the bath has caused some operators to introduce a little tar or oil with the gas after the melting process is complete.

The necessity for a luminous flame is determined to a great extent by the character of the charge; that is, the relative percentages of pig-iron and scrap. With a high percentage of pig-iron (60 to 65 per cent.), the bath has a great tendency to foam, and the simplest way of preventing the foam from slowing up the working of the furnace is to use some tar or oil. With a pig-iron value under 45 per cent. of the charge, the formation of foam does not become a factor, and the need for luminosity during the later part of the heat is not so pronounced. A number of plants have used coke-oven gas alone as fuel with such a charge and obtained very satisfactory results.

Furnaces operating with coke-oven gas alone and a high pig-iron charge maintain a higher furnace temperature throughout the heat than is normally considered good practice with the resultant decrease in life of roof. However, reasonable life is obtained with a good fuel consumption per ton.

Coke-oven gas may contain considerable sulphur in the form of hydrogen sulphid. The action of the sulphur on the fuel has been very thoroughly covered by Mr. A. N. Diehl in his paper on "Action of Sulphur in Basic Open-Hearth Steel Practice" published in the 1926 *Year Book of the American Iron and Steel Institute* (p. 404). The author points out that in a reducing atmosphere sulphur will be absorbed from the flame by both the scrap and the slag, but that in an oxidizing atmosphere the opposite effect is obtained. The elimination of the sulphur absorption from the fuel in the open-hearth furnace lies in proper combustion. If the design of the port and the placing of the burner are correct to give intimate mixing and rapid combustion, very little flame will be present in the furnace and practically no sulphur absorption by the bath will take place.

Natural Gas. The physical characteristics of natural gas are very similar to those of coke-oven gas. The direction and position of the flame in the furnace are dependent almost entirely on the air stream and are controlled by the design of the air port. The usual method of burning natural gas consists of having the air port give the desired position of flame and introducing the gas into the air stream from two opposed pipes extending through the side walls of the port directly in front of and slightly below the bridge wall. In this system a considerable amount of premixing may be accomplished, or a long luminous flame may be produced. During recent years a number of plants have introduced the gas through one burner extending through the bulkhead and part way across the air uptake into the port of the furnace. Such a method requires the accurate placing of the burner, but, when properly located, gives a very intimate mixture of gas and air with very early ignition, short flame, and high flame temperature.

Methods of Increasing Flame Temperature. In open-hearth furnace practice, only the heat developed above the temperature of the

materials in the bath is available for absorption. Also the higher the flame temperature the greater is the rate of heat transfer, and consequently the shorter the time required for making a heat of steel. For best operation it becomes essential that the flame temperature be maintained at as high a point as possible consistent with furnace life. The principal factors which determine flame temperature in any combustion process, in addition to calorific value of fuel, are the amount of preheat or sensible heat of fuel and air, quantity of air used for combustion, and the intimacy of mixture of fuel and air.

Value of Preheating Air and Gas. Table III has been prepared to show, for the different fuels shown in Table II, the theoretical flame temperatures obtained with varying amounts of preheat for fuel and air.

It will be noted that the percentage of heat in the fuel available for absorption in the open-hearth furnace has been shown in addition to flame temperature. The average temperature of the bath of an open-hearth furnace is approximately 3000 degrees F., so that only such heat as is developed above this point is available for transfer from the flame to the bath. The values shown were calculated on this basis. The marked increase in available heat with an increase in air preheat is very evident.

In order to obtain high preheat it is essential that the waste gases leaving the hearth of the furnace reach the checker chamber with a minimum of heat lost to radiation, and also that loss of temperature due to dilution by cold infiltrated air be prevented. Mr. T. J. McLoughlin in his paper, "Theory and Application of Regenerative Principles in the Steel Industry," published in the 1929 *Year Book of the American Iron and Steel Institute* (p. 159), points out the great loss in temperature which results from infiltration of air. With proper insulation of checker chamber and flues the air infiltration and heat radiation can be very materially reduced from the amounts existing with present open-hearth construction.

Mr. McLoughlin has also covered very capably the design of the checker chambers. He points out the need for materially increasing the heating surface available for preheating the air, and in addition calls attention to the great tendency towards channeling which exists in many brick checker chambers. The problem of dust deposits

TABLE III. THEORETICAL FLAME TEMPERATURE AND PERCENTAGE OF CALORIFIC HEAT AVAILABLE IN HEARTH

Temperature of fuel F.	Temperature of air F.	Natural gas Temp.	Natural gas %	Coke-oven gas Temp.	Coke-oven gas %	Producer gas—Rich Temp.	Producer gas—Rich %	Producer gas—Lean Temp.	Producer gas—Lean %	Mixed gas Temp.	Mixed gas %	Coke-oven tar Temp.	Coke-oven tar %	Fuel-oil Temp.	Fuel-oil %
60	60	3710	23.2	3840	26.5										
	1000	4215	41.3	4330	43.4										
	1600	4550	53.7	4620	55.0										
	2200	4870	66.6	4950	67.1										
1000	60					3460	18.4	3370	14.9	3610	22.7				
	1000					3815	32.9	3700	29.7	4010	38.7				
	1600					4050	42.8	3930	39.8	4290	49.6				
	2200					4280	53.3	4160	50.5	4570	60.9				
1600	60					3665	27.0	3580	24.2	3775	29.0				
	1000					4015	41.4	3910	39.0	4170	45.0				
	1600					4240	51.3	4140	49.0	4450	55.9				
	2200					4460	61.8	4370	59.6	4710	67.2				
2200	60					3885	36.2	3800	34.1	3960	36.1				
	1000					4220	50.6	4140	48.8	4340	52.1				
	1600					4135	60.5	4350	58.9	4610	63.0				
	2200					4650	71.0	4585	69.7	4870	74.4				
200	60											3910	28.3	3930	28.6
	1000											4400	45.0	4420	45.2
	1600											4720	56.4	4740	56.5
	2200											5010	68.3	5050	68.3

also materially affects the design, so that the proper design of checker chamber which gives the best average heat interchange during the life of a furnace is a compromise between that which will give the best theoretical heat interchange and that which will remain open to the passage of gas throughout the campaign.

With the introduction of heat-resisting alloy steel as a material for building air regenerators, it is possible to design means for preheating the air which will eliminate these difficulties. The installation would comprise a metal regenerator operating in series with the brick checker chambers. The waste gases pass first through the brick chambers and then through the metal regenerator, while the cold air going to the furnace is partly heated in the metal regenerator before passing on through the brick checkers to the furnace. Such an installation is shown in Fig. 1. The brick checker chambers can be

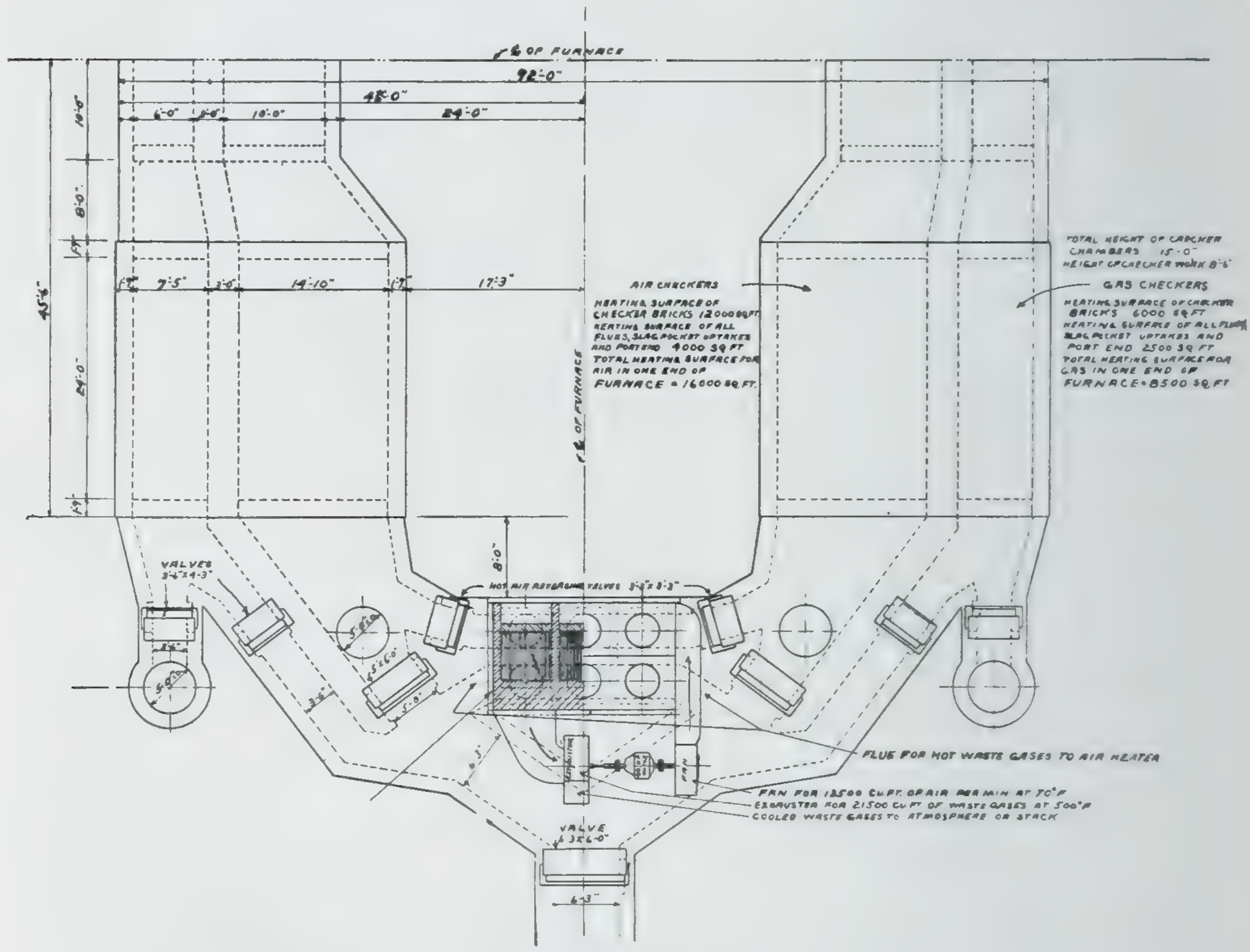

Fig. 1. Continuous Regenerative Air Heater.

designed to prevent clogging with dust and with only sufficient heating surface to absorb the peak temperatures from the hot waste gases, with the metal regenerator receiving the waste gases after they have

passed the brick checkers. In this way a large amount of heating surface can be made effective within a small floor space, and temperatures much in excess of present air temperatures obtained.

In many plants at present, the size of heats from given furnaces has been gradually increased so that even if the checker surface originally provided was sufficient, the increased production has rendered it entirely inadequate. In such plants the use of metal regenerators to increase the present heating surface provides a simple and economical means of obtaining higher air preheat with consequent lower fuel consumption per ton of ingots.

The use of blast-furnace gas and coke-oven gas mixtures as fuel for open-hearth furnaces necessitates the preheating of the fuel gas as well as the air. The air required for combustion of such fuels can not absorb sufficient heat from the waste gases to give a low stack temperature and economical furnace operation. It is also essential to preheat both fuel and air in order to maintain the desired furnace temperatures with a minimum of coke-oven gas in the mixture. In addition, it has been pointed out that the coke-oven gas requires high preheating in order to crack the hydrocarbons and produce a luminous flame.

Furnace Regulation. The flame temperature of any fuel is reduced by the presence of excess air over that required for theoretical combustion. However, the higher the preheat applied to the air the less detrimental does the excess air become. On the basis of available heat above 3000 degrees F., the curves shown in Fig. 2 have been calculated for natural gas and coke-oven gas.

The curves show the decrease in available heat which accompanies an increase in excess air. It will be noted that the decrease is much more marked for the condition of low preheat. The curves point out the necessity for high preheat not only from the standpoint of available heat, but also to offset the detrimental effect on furnace fuel consumption from improper regulation. The proper ratio of air for combustion to the fuel fired should be maintained at all times throughout the heat, and also throughout the life of the furnace. Such operation requires that the first helper be provided with means which will accomplish the desired result either manually or automatically.

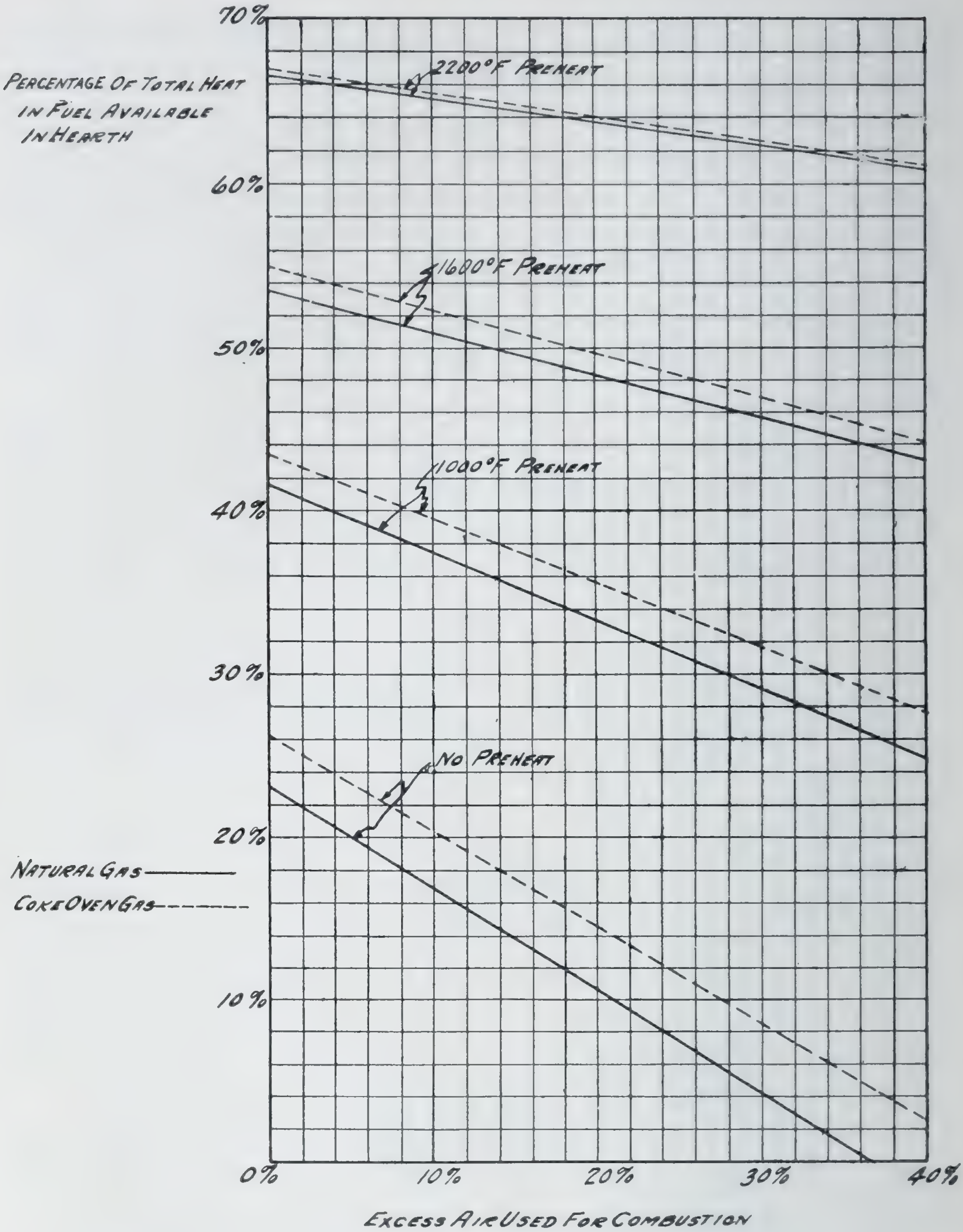

Fig. 2. Effect of Preheat and Excess Air on Available Heat in Hearth of Furnace.

Automatic regulation is closely connected with forced and induced draft. In order that air for combustion may be ample when the furnace becomes old, the air should be blown by a fan and correctly proportioned to the fuel by an automatic regulator or a manually operated valve operated in conjunction with indicating meters show-

ing fuel flow and air flow. The reversing valves must be tight as well as the flues and checker chambers, since proper air proportioning can not be maintained if the air blown by the fan is allowed to leak away instead of entering the port of the furnace. The draft for the furnace is another factor of prime importance. It should be possible to make the total stack draft available at the end of the checkers, if desired. This requires direct flues of ample size, equipped with straight-line-flow reversing valves in order to decrease the frictional losses. The stack draft should be automatically regulated at all times in order to maintain the necessary suction in the outlet port of the furnace required to clear the furnace of gases and protect the side walls and skewbacks from impingement of the flame. A material saving in refractory expense is obtained with furnaces which have the outlet end protected by the proper draft conditions, automatically maintained. It is needless to say that an excessive draft results in cold air being drawn into the furnace through doors and openings, thereby reducing the furnace temperature and slowing up the operation.

Design of Ports. The port of an open-hearth furnace is used alternately as an outlet and an inlet, and the design must consider both conditions. As the inlet, it gives direction to the flame and should provide for quick ignition in order to maintain maximum flame temperature. As the outlet, it should be capable of relieving the furnace of the waste gases under reasonable draft conditions and should withstand the high temperature and slagging action of the waste gases so as to maintain the correct lines required for the inlet conditions.

It has been pointed out earlier in the paper that the direction of the gas stream in the case of regenerated fuels, such as producer gas and mixed blast-furnace and coke-oven gas, is sufficient for determining the shape of the flame in the furnace. The lines and position of the gas port for these fuels are, therefore, of the utmost importance. When used for the exit end of the furnace the slagging action and high temperature to which it is subjected quickly changes the original shape unless proper water cooling is provided. The application of water cooling to this point of a furnace must be done very carefully. A minimum of water-cooled surface should be left exposed so as not to affect the furnace temperature. Means should be provided for

replacing the water-cooling parts in case of failure, and the application of the refractory covering should be simple and permanent. Such a port construction is shown in Fig. 3. It comprises a water-cooled

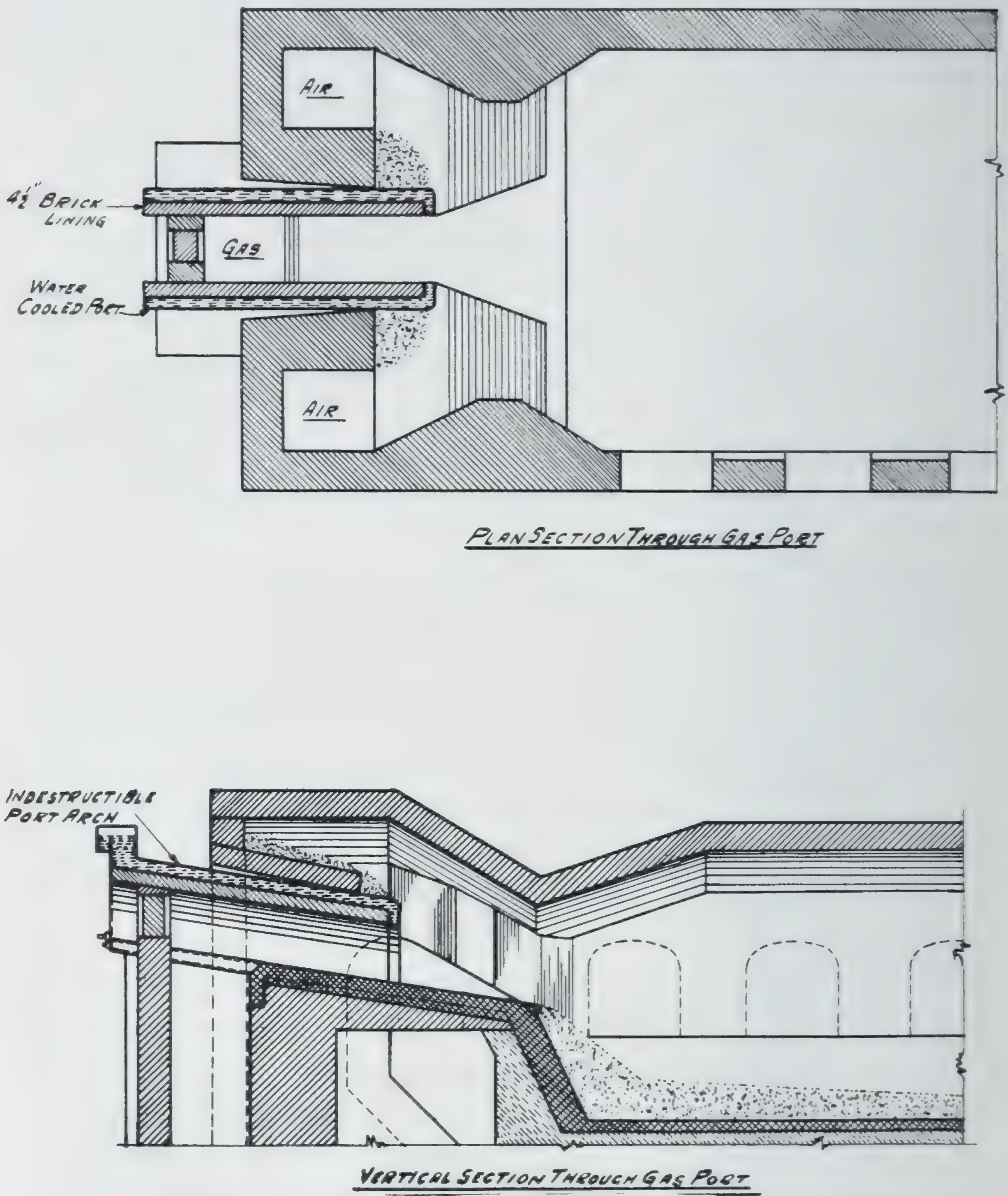

Fig. 3. Brick-Lined, Water-Cooled Port.

tank shaped to the lines of the port, and covered inside and outside with brick. Only the end of the port is exposed to the furnace and it can readily be removed through the bulkhead in case a leak develops.

Such port construction has given very satisfactory service in many plants throughout the country.

The gas port should be short, extending only part way toward the knuckle or restricted section of the complete port, while the lines of the air port should be such as to provide premixing of air and gas within the port, with consequent quick ignition and high flame temperature. The requisite velocity for the gas at the nose of the gas port is dependent on the length of the furnace, the ability of the gas stream to give up part of its velocity to the air stream in the process of mixing, and the ability of the available draft to clear the waste gases from the furnaces through the outgoing port. If a restriction to flow occurs at the outgoing end, the flame may tend to mushroom and severely damage the rear skewback and roof of the furnace at this point. For a normal 100-ton furnace the gas velocity at the nose of the gas port should be approximately 5000 feet a minute.

In order that a maximum flame temperature may be developed, it is essential that the combustion reaction be completed in as short a time as possible. Intimate mixture of air and fuel gives the quickest ignition and flame propagation. A port should mix the fuel and air as completely as possible and still deliver the air stream so as to protect the refractory material of which the port is constructed. The Venturi furnace fulfils these requirements admirably.

Conclusion. In conclusion, the problem of proper combustion still remains the maintenance of maximum flame temperature as Siemens originally discovered. High preheat, proper air regulation, and intimate mixing of air and fuel are the main factors to be considered. The danger to furnace life, due to high temperatures, is being solved in practice by correct design of furnace and ports.

The future development of open-hearth furnace operation and design will result in lower fuel costs with greater production, and must progress along the lines leading to higher and higher flame temperatures.

DISCUSSION

J. B. Crane:* I have been very much interested in the paper of the evening.

There seems to be a rather general idea that it is necessary to obtain a better grade of refractories in order to improve open-hearth furnaces.

I have had no experience with the operation of open-hearth furnaces, but when an engineer is designing a steel structure he gets the physical properties of the materials with which he has to build the structure, and designs the structure accordingly. If the structure falls down, the engineer is to blame. With refractories he builds a wall, and if the wall falls down, refractories are to blame.

In developing furnaces for pulverized fuel, we ran into the same difficulty, and in order to use refractory furnaces we had to build very large combustion chambers. By air cooling the refractories we were able to reduce the size of the furnace, and by lining the combustion chamber with water-cooling surface we were able to use a furnace about one-third the size that was necessary with plain refractories.

I am wondering if it would not be possible to try air cooling of the refractories in open-hearth furnaces, and in this manner secure better results. I notice the fact that you now depend largely upon the reflected heat from the roof, but this can not be the controlling factor, or you would insulate the roof and in this manner secure less radiation, and it would not require as much heat to melt the contents of the furnace.

In this connection we have built wet-bottom furnaces for the use of pulverized coal, and in these furnaces it is necessary to maintain a heat at the bottom of the furnace, which will allow the slag to run, and be tapped off at intervals, or in some of the later developments there is continuous running of the slag. The necessary heat is maintained at the bottom of the furnace to keep the slag in a molten condition, and yet the temperature of the gases at the top of the furnace is reduced to about 2000 degrees F. before entering the boiler tubes. The top of the furnace is entirely covered with black boiler surface instead of a refractory arch.

*District Manager, Combustion Engineering Corporation, Pittsburgh.

In these latest furnaces the firing is done from the corners, and in this way we obtain a very turbulent action of the coal and air required for combustion. It has been found that the temperature at this point is chiefly dependent upon proper mixing of fuel and air.

E. A. BROWN, JR.:* The open-hearth process at present is greatly limited by the quality of refractories available, and to my mind the brick manufacturers are far behind in aiding the improvement of the process. Were proper brick available, there are any number of improvements that could be made immediately.

If I may discuss Mr. Crane's remarks relative to solving the open-hearth problem by air cooling the furnace as is done with settings of pulverized-coal boilers I would call attention to the fact that the open-hearth furnace is now practically an air-cooled job, and were it not for the fact that the bricks in the furnace proper and hot fantails are laid in such a way as to allow filtration at every joint the furnace would not last as well as it does.

I have appreciated Mr. Chandler's treatment of this important subject and agree with him throughout with one exception. In the first paragraph of his paper I understood Mr. Chandler to say something to the effect that combustion in the open-hearth furnace, in general, was much the same as with other industrial furnaces. I can not agree with this. Personally, I believe that the open-hearth furnace, not unlike reversing reheating furnaces and pits to a certain extent, is one of the most contrary and baffling applications in the steel industry. I say this because the control of combustion is difficult and the application of controls is quite a problem. I disagree with Mr. Chandler's statement for the following reasons:

In the stack of a boiler furnace or a hot-blast stove it is not difficult to attain CO_2 analysis of 23 per cent., with a possible 26 per cent., and the same is true to a certain extent with continuous furnaces, but such efficiency can not at present be arrived at with the open-hearth furnace. The reason for the perfection in the above-mentioned illustration lies in the fact that combustion, air infiltration, and radiation can be reasonably controlled, whereas up to the present in the open-hearth furnace they have been controlled only to a limited extent.

*Assistant to Chief Mechanical Engineer, Carnegie Steel Co., Munhall, Pa.

I believe the following will illustrate the reasons for the above observations.

We have recently proved experimentally in the open-hearth furnace that the pressure (absolute) immediately under the roof in the center of the furnace is about 0.07 of an inch water-gage higher than at the sill plate elevation, or for about a five-foot difference in elevation. This figure checks up with calculations when we consider the intense temperature within the furnace. This accounts for the condition which may actually exist in which a furnace blows out at the top of the doors and still sucks air in at the bottom. The difference in draft intensity is then readily appreciated at the different elevations of the furnace and the checker system, which difference in elevation may amount to 30 feet of intense temperature. Consequently, as we make a balanced draft at any point in this system all other points will be put under either vacuum or pressure with consequent leakage outward or air infiltration inward, and it is this inconsistency of pressure and draft at various points which offers the difficulty with automatic-control equipment. It also accounts for the fact that if the mixture of gas and air in the incoming port is correct, then by the time it leaves the furnace it has been diluted by heavy air infiltration within the furnace; or, if the analysis is correct at the outgoing port, it was deficient in air at the incoming one and combustion within the furnace was generally imperfect.

Is there any open-hearth plant that can show approximately perfect analysis in the outgoing port and at the same time have a respectable air-free sample in the stack, or vice versa? I believe there are very few, if any.

Again consider the volume of an open-hearth system. Though the actual combustion zone is relatively small compared with the large bulk of ports, uptakes, checker chambers, flues, etc., these are made of porous brick, and, unless tightly closed, air leaks in in large volumes. At the same time, radiation occurs over this large surface, and the two together account for the poor efficiency of the open-hearth process in general.

This has been realized to such an extent that the Tennessee Coal, Iron and Railroad Company has in operation three or four banks of soaking-pits in which a very radical departure has been made. In arriving at this design they eliminated all checkers and other forms

of heat abstraction after the pit itself and, instead, installed Surface Combustion Company burners with forced cold air, and thereby considerably improved the old construction with regard to fuel economy.

Do not understand that I advocate this pit construction. It is evident that waste heat can be recovered, but I believe it does prove that control is more important than slip-shod heat abstraction, and control is what we lack at the present time, due to the large heat-radiating and air-infiltrating surface. This then leads to the cure. The tendency has been to effect a remedy by the addition of more heat-abstracting volume and thus cool the waste gases down to a lower temperature. This is only a superficial analysis. Adding more heat-abstracting surface in general will only aggravate the present difficulty by adding more resistance, necessitating additional draft which, in turn, will again produce more leakage radiation and adverse results.

A more sane application of forced air and possibly induced draft will aid in the solution. But first of all in importance is absolute tightness of valves, checkers, and flues, insulated as thoroughly beneath the charging floor as refractories will permit. When this is accomplished, automatic control of draft and air flow will be in order and improvement should follow, but always limited by refractories, unless the brick manufacturers advance considerably faster than they have shown signs of for some years back.

In past years we have failed to realize the great number of variables in the open-hearth furnace, and have tried to interpret the effect of one variable without reference to the others. Past experimental work, I believe, has in many cases been misleading, but I think from now on will be of more value.

You can not judge stack temperature without reference to analysis or excess oxygen, nor draft loss without reference to flow, nor can you measure air unless you know it all goes to the furnace instead of to the stack through a leaky valve. Neither can you say a furnace chamber is operating on slight excess pressure because gases lick out the top of the door. Above all, when a furnace operator says his furnace system is tightly sealed, just check up and see what his idea of tight means. You can still prove to him that tight is but a relative term and with most of our existing construction far from perfection.

WALTER DE FRIES:* I surmise from the trend of the author's paper that he proposes to increase the efficiency of open-hearth furnaces by transferring an additional amount of B.t.u. from the waste heat to the combustion air through auxiliary regenerators. A series of tables presented in support of this statement is evidently based on the heat carried back into the furnace through this auxiliary exchange without, however, touching on the effect, which the increase in air temperature will have on the combustion reaction. In other words, the author assumes that combustion temperatures will keep on increasing, corresponding to the amount of preheating done, and the temperature gradient between the open-hearth flame and the bath will become accordingly greater, so that more heat is transferred in a given time.

Numerous experiments that I made several years ago with open-hearth furnaces along this line of reasoning have convinced me of the utter fallacy of such argument. I have in mind particularly the installation of a highly efficient combustion device on a natural-gas-fired open-hearth furnace, which embodies all the recommendations made in the author's paper for increasing open-hearth efficiency, but which in actual trial did not improve the output from the furnace or the fuel economy one bit.

In searching for an explanation of this occurrence I came across some very valuable data published in "Technische Thermodynamik,"† by W. Schüle, as the only reference giving a logical explanation for my observations, in a discussion on dissociation of combustion products under temperature conditions as existing in the open-hearth furnace. The data presented in this reference show that with a temperature of 1300 degrees C., or 2372 degrees F., the dissociation range begins. Examples presented for the combustion of air-gas with an initial temperature of 20 degrees C. and 800 degrees C., respectively, for both air and gas entering into the combustion reaction show a degree of dissociation of only 1½ per cent. for the combustion resulting from the unpreheated fuel and air, which increases to fully 18 per cent. with the fuel and air preheated to only 800 degrees C., or about 1450 degrees F.

*Chief Engineer, William B. Pollock Co., Youngstown, Ohio.
†Ed. 2, 2v. 1912-1914. Julius Springer, Berlin.

The explanation for such occurrences is found in the laws of chemical equilibrium applying to fuel-gas mixtures ordinarily consisting of CO_2, H_2O, and N_2 with possible excesses of O_2.

I was also able to find a practical demonstration of the truth of this statement in analyzing the history of this particular furnace during its previous campaigns. It appeared that whenever the furnace was started up after each rebuilding and the entire furnace system accordingly cooled down, the first heat would come out of the furnace at a fuel rate of approximately 5,000,000 B.t.u., which gradually increased to between 6,000,000 and 7,000,000 B.t.u. per ton as the regenerators became more effective due to operation of the furnace, so that the air preheat was improved, just as the author of this paper recommends.

Summarizing this explanation, I would state that there is an economic limit beyond which either fuel or air, or both, for open-hearth combustion should not be preheated. If carried beyond this most advantageous condition, which, of course, varies with the different fuels, additional preheat will inhibit the combustion reaction instead of helping it.

Air preheating can be overdone, and particularly so in open-hearth furnaces, and before accepting the recommendations made by the author of this paper I would suggest that each particular condition be subject to careful analysis of the flame temperatures to be expected.

The furnace arrangement shown involving the delivery of air to the furnace by means of a motor-driven fan may be a very desirable arrangement for a number of installations I know of, which do not have sufficient fuel capacity, but any benefits obtained from the furnace with such an arrangement are more likely to result from the fact that the air is forced into the furnace by means of the fan rather than from the installation of the auxiliary regenerator.

To ascertain what benefits can be derived from additional air preheat under given local conditions, two furnaces equipped with forced-air delivery should be compared—one with and the other without the auxiliary air preheater. Comparing a furnace depending on updraft in checkers for its air supply with one equipped with auxiliary regenerators plus forced air delivery is apt to lead to incorrect con-

clusions as to the benefits obtainable from the addition of the auxiliary regenerator proper.

W. P. CHANDLER, JR.: The discussion has brought out many points of value and indicates very clearly the general need for refractory materials which will withstand higher temperatures than at present. We trust that the experimental and development work which is being carried on by various manufacturers will result in an advance in this direction in the near future.

We agree thoroughly with Mr. Brown in his plea for tightness in open-hearth furnace systems and for proper regulation. The laws governing combustion are the same for the open-hearth furnace as for any other steel-mill combustion unit, and the demand for high air preheat is more acute in the open-hearth furnace due to the much higher temperature desired for this process. The maximum economy of operation for an open-hearth furnace is reached with maximum preheat, in conjunction with proper tightness, regulation and insulation.

Mention was made of soaking-pits constructed with no air regeneration. Such construction naturally means a direct loss of valuable heat. The elimination of regenerative heating surface for combustion air, because of difficulty in constructing it without serious losses, does not seem to be in the nature of progress. It might be of interest to note that for the soaking-pit installation mentioned, the application of preheated air is now being seriously considered.

The discussion presented by Mr. de Fries relative to the detrimental effect of high preheat fails to take into account one factor of prime importance. The fact that the burning gases radiate heat during the formation of the flame to the cooler bath, walls, and roof of the furnace results in an actual flame temperature considerably below the theoretical. Also the amount of dissociation occurring at different temperatures as given by Mr. de Fries does not agree with data used by R. T. Haslam and R. P. Russell in their treatise on "Fuels and Their Combustion."* A series of pyrometric measurements of flame temperature actually developed in an open-hearth furnace supplied with highly preheated air and using a mixture of coke-oven gas and tar as fuel shows that 3400 degrees F. is seldom obtained. In such a flame having the proper amount of air and with a proper

*1926. McGraw, New York.

degree of mixing, the drop in temperature from the theoretical is caused by radiation to cooler surfaces during the formation of the flame. From the information on dissociation of water vapor and carbon dioxid given by Haslam and Russell the maximum dissociation would not amount to over seven per cent. instead of over 18 per cent. as stated by Mr. de Fries.

The value of preheat must also be considered on the basis of availability of heat. As mentioned in the paper, the total heat supplied to the hearth of a furnace should not be taken as a basis for calculating efficiency, but rather the amount of heat above some basic temperature available for absorption. On such a basis any heat introduced into the furnace as additional preheat increases directly the amount of available heat since it tends to increase the flame temperature. In practice, the various methods used for obtaining higher flame temperatures which have been thoroughly tried out have resulted in an increased economy.

APPLICATION OF CENTRIFUGAL FANS*

By C. A. Carpenter†

During the latter part of 1911 and the early part of 1912, the author became interested in some fundamental mathematical relations applying to centrifugal machinery. A very interesting paper had been presented by Chester W. Larner, then chief engineer of the Wellman-Seaver-Morgan Company, entitled "Characteristics of Modern Hydraulic Turbines," published in the *Transactions of the American Society of Civil Engineers,* volume 66, page 306.

Mr. Larner's paper developed the theory of specific speed applied to water turbines for specific conditions of service. The author modified some of the mathematics outlined by Mr. Larner and developed the theory of specific speed, as applied to centrifugal pumps and centrifugal fans.

Amplifying this theory led to the conclusion that complete characteristic curves could be plotted, using specific speeds as abscissæ and efficiencies as ordinates, provided the basic design were known by suitable tests.

Much of this material was published by the author in *Power,* volume 35, April 30, 1912, p. 612, in a paper entitled "Comparing Turbo-Pumps, Blowers" and in the *Electrical World,* volume 61, June 14, 1913, p. 1309, in a paper entitled "Design and Operating Features of Motor-Driven Pumps." Later, Prof. T. G. Estep, of Carnegie Institute of Technology, and the author presented a paper before the Engineers' Society of Western Pennsylvania, entitled "Characteristics of Centrifugal Fans," published in the Proceedings, volume 43, p. 306.

The author has published other papers on this general subject, among which might be mentioned:

"Variable Speed Drive for Centrifugal Pumps." *Engineering Record,* volume 65, June 8, 1912, p. 629.

"Application of Engineering to Mine Fan Selection." *Mining Congress Journal,* volume 14, November 1928, p. 833.

*Presented February 11, 1930. Received for publication April 30, 1930.
†Hydraulic Press Mfg. Co., Mount Gilead, Ohio.

"Engineering Aspects of Unit Heater Design." *Heating and Ventilating Magazine,* volume 26, April 1929, p. 71.

"Limitations of Direct-Connected Fans Operating at Fixed Speeds." *Heating and Ventilating Magazine,*" volume 26, May 1929, p. 60.

"Elementary Fan Engineering." *Heating and Ventilating Magazine,* volume 26, September 1929, p. 63; October 1929, p. 82.

The mathematical relationships of fan performance can be carried much further than in the material heretofore published.

It is interesting to note that specific speed is a term known to water turbine engineers for many years, to centrifugal pump engineers (and in rather general use) since 1912, and yet scarcely known to fan engineers after 18 years of publicity, despite the fact that many technical men have contributed papers on this subject since 1912.

About twenty years ago, many centrifugal pumps were offered to the trade with impeller vanes curved forward in the direction of rotation. A short while ago the American Society of Mechanical Engineers heard three scholarly papers on centrifugal pumps. These papers, mentioned below, appear in the *Transactions of the American Society of Mechanical Engineers,* 1927–1928, volumes 49-50, pt. 2. (The rather cumbrous symbol following each reference is required for its definite identification.)

"New Method of Separating the Hydraulic Losses in a Centrifugal Pump," by M. D. Aisenstein (HYD-50-2; HYD-50-6).

"Method of Analyzing the Performance of Centrifugal Pumps," by Joseph Lichtenstein (HYD-50-3).

"Centrifugal Pumps," by H. T. Davey (HYD-50-4).

None of these authors even discussed forward-curved vanes. They all clearly showed that backward-curved blading was practically universally accepted and Mr. Davey referred to specific speed.

Furthermore, it is worthy of note that turbo-blower manufacturers have developed radial and backward-curved blading despite the fact that, theoretically, forward curvature of impeller blades should produce pressure with lower rim speeds, and, as is well known, rim speed becomes a real problem in turbo-blower design.

Why is it that fan manufacturers have failed to adopt the scientific development of their designs and applications? The author ventures an opinion as follows. Water is heavy and easily observed. In both water turbines and centrifugal pumps, volumes are relatively low and pressures high. In turbo-blowers also, volumes are relatively low and pressures high. Large horse-powers are involved. In proportion to the physical size of the equipment, the power is great. With fans, oftentimes, conditions are just the reverse. Air is not very noticeable; usually volumes handled by fans are large and pressures low. Power in proportion to physical size is generally low. Hence handling a substance, not very noticeable, in a large machine with what appears to be little power, has led to careless thinking and fan manufacturers have not been compelled to give thought to scientific engineering as has been the case with manufacturers of water turbines, centrifugal pumps, and turbo-blowers.

Fans delivering 100,000 cubic feet per minute are common; but 100,000 cubic feet of water would correspond to approximately 750,000 gallons, and a pump delivering 750,000 gallons per minute would be some pump. Pressures of 200 feet are not abnormal with pumps; 200 feet of water corresponds to a pressure of about 86.8 pounds. Such a pressure, of course, is absolutely out of all range of ordinary fans.

At this point, it is interesting to note that the two following simplified formulæ are identical:

Water horse-power $= \frac{cp}{3960}$, in which $c =$ gallons per minute and $p =$ head in feet of water.

Air horse-power $= \frac{CP}{6356}$, in which $C =$ cubic feet per minute and $P =$ pressure in inches of water-gage.

Taking the formula for water horse-power $= \frac{cp}{3960}$ and changing c (gallons per minute) to C (cubic feet per minute) we must multiply by 7.48. To change p (head in feet) to P (head in inches) we must divide by 12 in order to have the same developed water horse-power; $\frac{7.48CP}{12 \times 3960} = \frac{CP}{6356}$, approximately.

The very slight discrepancy is due to the fact that hydraulic engineers use 62 degrees F. while fan engineers ordinarily use 70 degrees as a basis for pressure readings and there is a slight difference in water pressure per foot of height due to this difference in temperature.

The foregoing comparison of formulæ is given because it clearly shows that the horse-power to handle a fluid is a function of volume delivered and pressure. Temperature enters the formula only in its effect on the measurement of pressure.

The horse-power required to deliver 100,000 cubic feet per minute of any gas against a low pressure—as one ounce—is independent of the density of the gas unless fan efficiency varies. The pressure, if read in inches of water, should be corrected for the temperature of the water.

Two outstanding relations apply to fans within the scope of ordinary practice as generally observed.

For any fixed point of operation—as, for example, normal rated capacity at maximum efficiency—the pressure produced is a function of tip or rim speed and the density of the gas handled.

This may be expressed thus:

$$X = \frac{\pi d N}{12 \times 4005 \sqrt{P}}$$

X = a ratio.
d = diameter of fan wheel or impeller in inches.
N = revolutions per minute.
P = pressure in inches of water-gage.

Capacity $C = \dfrac{\pi w d^2 yN}{6912}$.

C = cubic feet delivered per minute.
w = width of fan wheel in inches (average).
y = volumetric efficiency of the fan expressed decimally, or the ratio of air delivered per revolution to the cubical contents of the wheel.

By simple algebra, $y = \dfrac{6912\, C}{\pi w d^2 N}$.

From a theoretical consideration of these formulæ many conclusions may be drawn. Since it conforms to general practice and

is confirmed by tests published so far, that fans of identical design have definite ratios, X, of tip speed to theoretical air speed corresponding to the pressure produced (when due correction is made for temperature, barometer, humidity and other factors affecting density) and such fans have definite corresponding volumetric efficiencies, y, fan tables may be prepared by calculation for various standard sizes based on tests of one or more fans of the same design.

Hence, if a fan be tested, a fan twice as large operating under similar density conditions at the same number of revolutions per minute, N, and at the same relative efficiency would be expected to deliver eight times the volume at four times the pressure. Furthermore, the outlet area would be four times as great. The outlet velocity, therefore, would be twice as great and the outlet velocity head, varying as the square of the velocity, would be four times as great.

It will be noted that the relations between actual pressures produced—either total or static to the outlet velocity heads—do not vary. In other words, in present practice, the ratios of static pressures to total pressures are functions of basic design and relative points of operation. These ratios are assumed to be independent of size of fan and density of gas handled.

These conclusions have led to the use of characteristic curves to explain fan performance. Such curves may show actual definite tests or may be converted to a percentage basis usually showing the variation in total pressure, static pressure, horse-power, efficiency, and ratio of static to total pressure plotted as ordinates against percentages of rated volume as abscissæ.

Unfortunately such curves, while quite complete in themselves, do not solve the real problems of application and much more definite means should be provided to help engineers. It is the purpose of this paper to show how new characteristic curves and diagrams can be developed mathematically to help engineers without in any way deviating from the science of fan engineering as known to-day, and yet being sufficiently flexible to permit adaptation to an improved fan technique.

The author wishes to stress the point that this paper takes science as accepted by fan builders and users, but shows how to apply

this science easily and correctly in solving a problem of fan application. It may be said that this is now being done. Only a cursory glance is necessary to convince an observer that most fans are wrongly applied or are very inefficient. This applies to mines, steel-mills, power-houses, public buildings, and the other myriad uses of machinery to force or to draw gases into circulation.

While this statement may sound like an exaggeration, analysis of fundamental fan relations as published at present reveals the cause. At any constant speed for a given design and size of fan, the relation between the quantity C in cubic feet per minute delivered, and the pressure P developed, may be shown by a line curve known as the fan characteristic. For an airway of unchanging dimensions and unchanging surface another definite relation exisits between the quantity C and the pressure P. This, as generally stated, is that the pressure varies as the square of the volume or velocity. Some deviation from an exact parabola may occur due to changes of temperature through air travel, etc.

A centrifugal fan, therefore, must perform at the one point where the curve of airway relationship intersects the fan characteristic at any instant. If this intersection does not occur where fan efficiency is reasonable (near the point of best efficiency), a loss occurs that may reach enormous values. It is also possible that the fan may fail miserably in its service by delivering much less volume than required.

A general algebraic statement of fan relations will make this clear. In the paper given by Prof. T. G. Estep and the author, published in volume 43 of the PROCEEDINGS, the derivation of one formula for specific speed was given. This formula is as follows:

$$K = \frac{N\sqrt{C}}{79.72\, P^{3/4}}\,.$$

At this point the nomenclature used throughout the paper will be stated:

K = specific speed.
K_T = total pressure (specific speed).
K_S = static pressure (specific speed).
K' = specific speed for 100 revolutions per minute. (N = 100.)

N = revolutions per minute.
C = cubic feet delivered per minute.
P = pressure in inches of water-gage corrected to dry air at 70 degrees F. and 29.92 inches of mercury.
P_S = static pressure.
P_T = total pressure.
P_V = velocity pressure.
E = efficiency.
E_T = efficiency based on total pressure.
E_S = efficiency based on static pressure.
AHP = air horse-power.
$(AHP)_T$ = air horse-power based on total pressure.
$(AHP)_S$ = air horse-power based on static pressure.
BHP = brake horse-power $= \dfrac{AHP_T}{E_T} = \dfrac{AHP_S}{E_S}$.
V = velocity of flow in feet per minute.
d = diameter of fan wheel in inches.
w = algebraic average width of fan wheel in inches.
X = ratio of tip or rim speed to theoretical air speed corresponding to water-gage corrected to dry air at 70 degrees F. and 29.92 inches of mercury.
X_T = ratio based on total pressure.
X_S = ratio based on static pressure.
y = volumetric efficiency of the fan, or the ratio of air delivery per revolution to the cubical contents of the wheel.

$$C = \frac{\pi d^2 w N y}{6912} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$X = \frac{\pi d N}{12 \times 4005 \sqrt{P}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Substituting (1) and (2) in the formula $K = \dfrac{N\sqrt{C}}{79.72\, P^{3/4}}$ we get

$$K = 505.98\, X^{3/2} \sqrt{\frac{w}{d}\, y} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The formula $K = \dfrac{N\sqrt{C}}{79.72\, P^{3/4}}$ shows the specific speed required

by the job. Formula (3) shows the specific speed based on fan design. In operation, of course the two formulæ must be identical.

For eighteen years, the author has been using specific speed in connection with pumps and fans. Many tables of fan performance have been analyzed with the result that some general conclusions may be drawn as to standardized fan performance. Most performance tables of fans of any given design are based on the following assumptions:

1. The volumetric efficiencies may be computed from cubic feet per minute, wheel dimensions, and revolutions per minute.

2. Corresponding to a value of volumetric efficiency y there are definite values of ratios X_T and X_S and efficiencies E_T and E_S.

3. These relations are independent of N, wheel dimensions d and w, and revolutions per minute.

That these statements are not absolutely true must be evident, but within ordinary operating speeds of fans of standard design they are probably as nearly correct as can be determined by ordinary current methods of fan testing. Undoubtedly a very wide variation in revolutions per minute would reveal considerable variation in efficiency and any great change in dimensions would show variations in performance.

Taking these relations as being vitually true as commercially used, we can draw many interesting conclusions from the formulæ

$$K = \frac{N\sqrt{C}}{79.72\,P^{3/4}}\text{, and } K = 505.98\,X^{3/2}\sqrt{\frac{w}{d}\,y}.$$

Since the number of cubic feet per minute, C, and the pressure, P, are determined by conditions surrounding any job, the specific speed, K, can be varied only by changing the revolutions per minute, N. This clearly accounts for the desire on the part of manufacturers featuring standardized designs to select their own speeds. As a result many expedients are in vogue.

Fans may be driven indirectly by belts, chains, gears, etc., in order to obtain selected speeds. Variable-speed motors may be suggested in order to mask the limitations of any particular design. In such cases the fan may be designed to operate well below the maximum moter speed. Steam drives are still used because speeds may be chosen to fit the standard fan design.

Considering formula (3), $K = 505.98\, x^{3/2} \sqrt{\frac{w}{d}\, y}$, it is evident that all features of a good design may be preserved if K may be set by the fan manufacturer. However, problems are arising with increasing rapidity in connection with centrifugal machinery in which K is fixed by conditions beyond the control of the manufacturers of centrifugal machinery.

Many years ago water turbine builders faced this problem and "specific speed" became a tangible fact to them. If we consider that water-power is available in varying volumes and heads but that speeds of the driven generators are quite limited, it is readily seen why water turbine designers analyzed their problem.

During the past 15 years, belt-driven centrifugal pumps have nearly disappeared but indirectly driven fans predominate.

Approaching the problem solely from the viewpoint of fan manufacture, let us examine formula (3). We have three variables as follows:

X = ratio of tip speed to theoretical speed of air corresponding to water-gage corrected to dry air at 70 degrees F. and 29.92 inches of mercury.

y = volumetric efficiency expressed decimally.

$\frac{w}{d}$ = ratio of average width of wheel to diameter.

It has been stated that within the limits of ordinary fan practice X and y are fixed for any design for any specific condition such as no delivery, 20 per cent. of full open delivery, free delivery, etc., and for each of these conditions definite efficiencies are obtained (approximately) regardless of revolutions per minute or wheel diameter. For no delivery, $y = 0$, $E = 0$, X depends on design. For free delivery, X_s = infinity, $E_s = 0$, y depends on design.

The relation $\frac{w}{d}$ appears offhand to offer the easiest method of varying specific speed, therefore we find many fan builders, offering fans of one type and wheel diameter combined with two or more widths. There are limits, however, to the value of $\frac{w}{d}$ if efficiency is to be maintained. Wide wheels necessarily have relatively restricted

inlets, while very narrow wheels have high friction losses through the wheel and due to the exposed sides of the wheel. Since the variation of K is as the square root of $\frac{w}{d}$ the ultimate range of specific speed due to permissible variations in wheel width is comparatively small.

Varying X and y has fascinated fan designers for many years; hence the many odd-shaped blades, inlets, wheel tapers, scrolls, etc. The disappointing phase of this history is the fact that for good efficiency with various prevalent designs. X goes down when y goes up, thus largely keeping these two factors in balance.

The product Xy which we shall call capacity factor Z has interesting algebraic possibilities.

From equation (1), $C = \frac{\pi d^2 w N y}{6912}$, and $y = \frac{6912\, C}{\pi d^2 w N}$.

From equation (2), $X = \frac{\pi d N}{12 \times 4005 \sqrt{P}}$.

Therefore $Z = Xy = \frac{576\, C}{dw \times 4005 \sqrt{P}}$.

Capacity factor Z takes into consideration the following:

Capacity in cubic feet per minute, C.

Pressure in inches of water-gage, P, corrected to dry air at 70 degrees F. and 29.92 inches of mercury.

Diameter of wheel in inches, d.

Width of wheel in inches, w.

Since for any correlated values of X and y, there are corresponding values of efficiency E_T and E_S for a given design, performance curves using Z as a base and values of E as ordinates may be plotted.

Fig. 1 shows some representative curves with values of K as abscissæ and corresponding values of E and X as ordinates.

Fig. 2 shows curves using Z (capacity factor) as abscissæ and corresponding values of E and X as ordinates.

It is to be hoped that fan manufacturers will co-operate with their customers by publishing charts of performance of their various designs plotted as in Fig. 1 and 2. Engineers interested in fan appli-

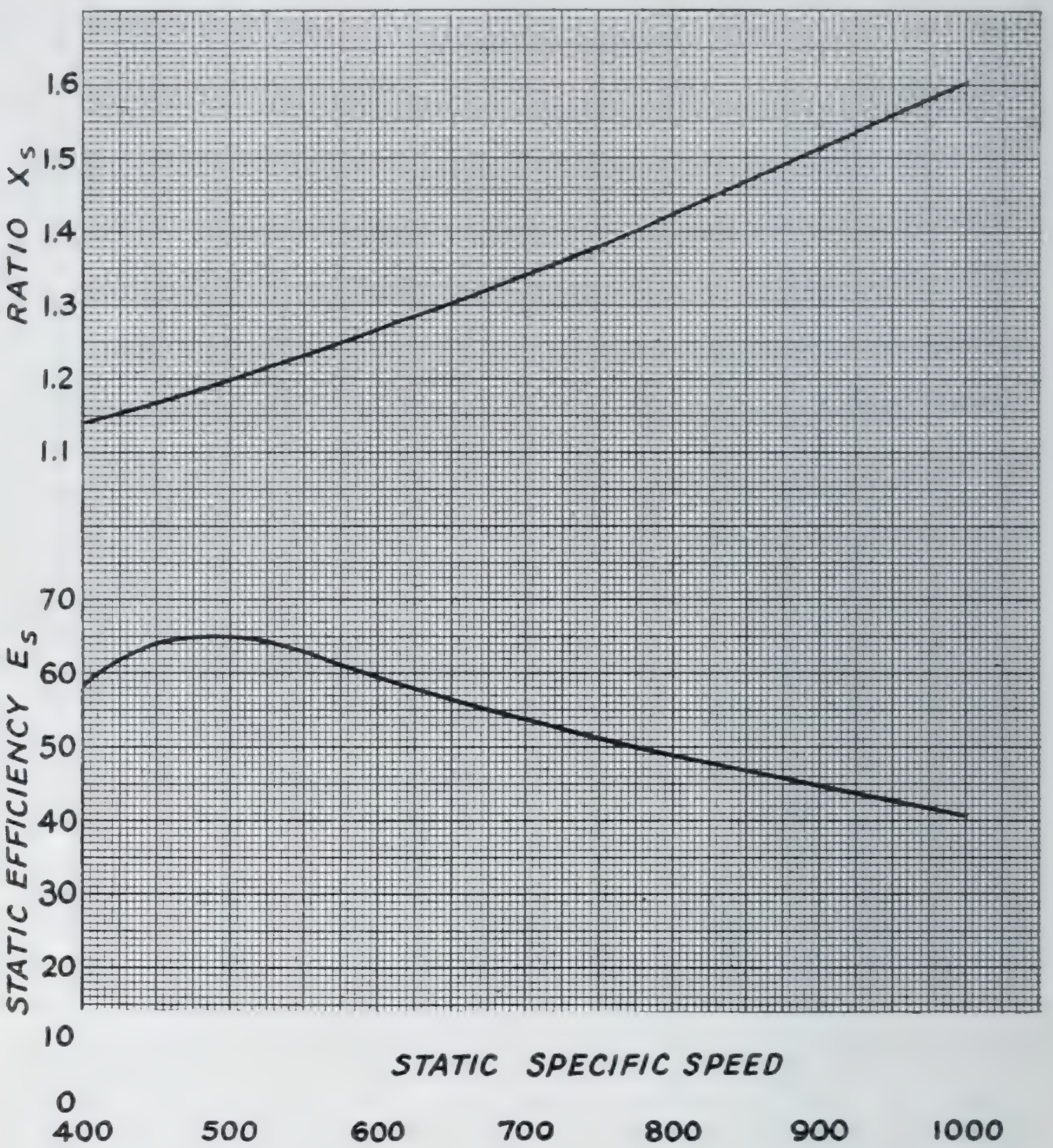

Fig. 1. Efficiency and Ratio Plotted against Specific Speed.

cations could then aim to keep specific speed within desirable limits and could check capacity factors Z from the required capacity, pressure and wheel dimensions. This method would completely solve fan problems involving choice of speed by the fan manufacturer. It would also turn the light on the engineering investigation yet necessary to offer to the trade truly efficient direct-connected fans that would be comparable with modern centrifugal pumps.

In order to visualize fan performance in a broad way, the author has developed charts from the following algebraic analysis:

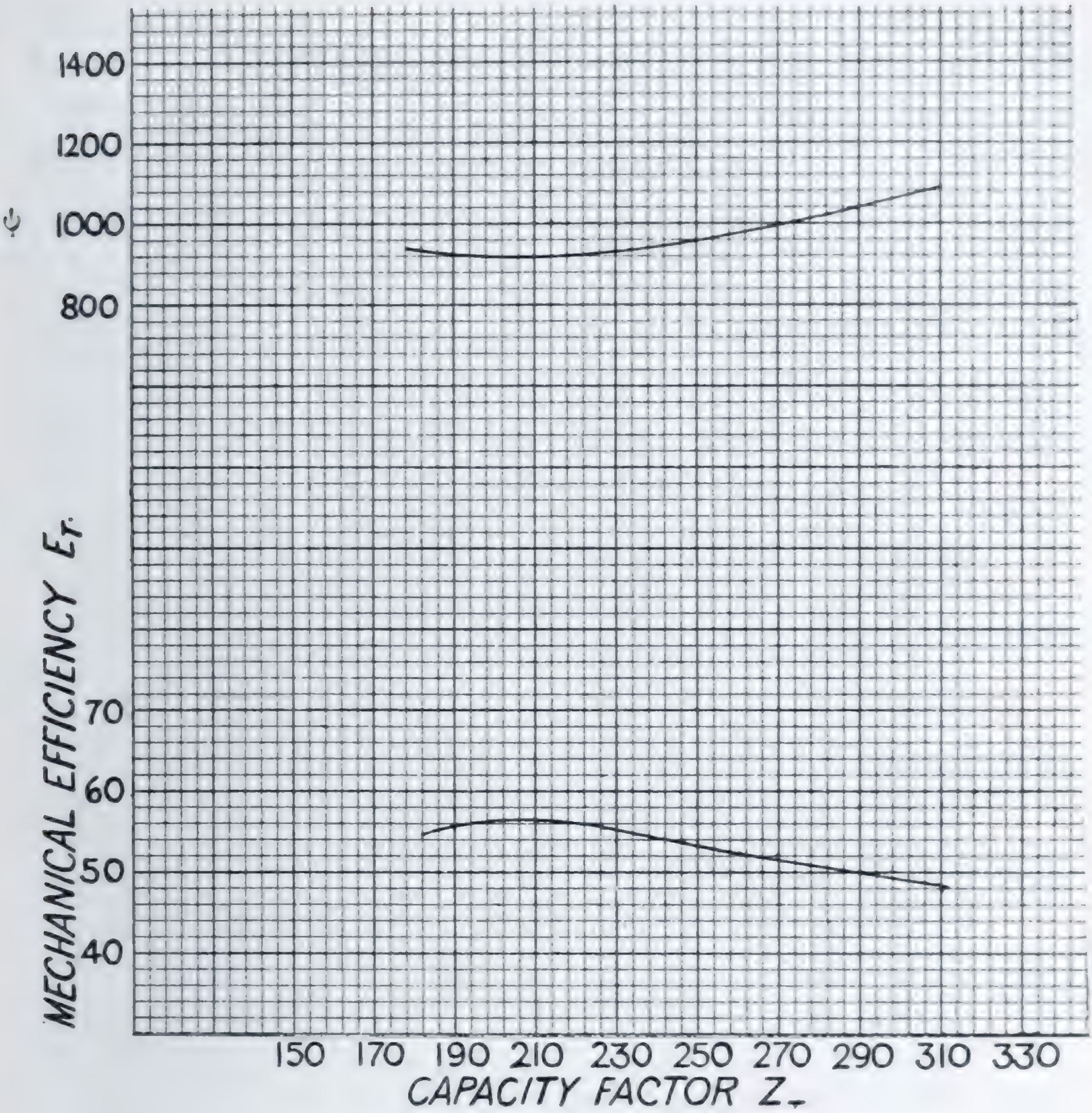

Fig. 2. Efficiency and Ratio Plotted against Capacity Factor.

Since capacity factor $Z = \dfrac{576\,c}{dw \times 4005\sqrt{P}}$, $\dfrac{c}{\sqrt{P}} = \dfrac{4005\,Zdw}{576}$.

Since Z varies from 0 to some maximum desirable limit for each type of fan, a chart may be prepared showing standard values of d; w being a function of d with Z as abscissæ and $\dfrac{c}{\sqrt{P}}$ as ordinates.

Fig. 3 shows radiating lines with wheel diameters given in feet with scale for a value of 0.5 for $\dfrac{w}{d}$.

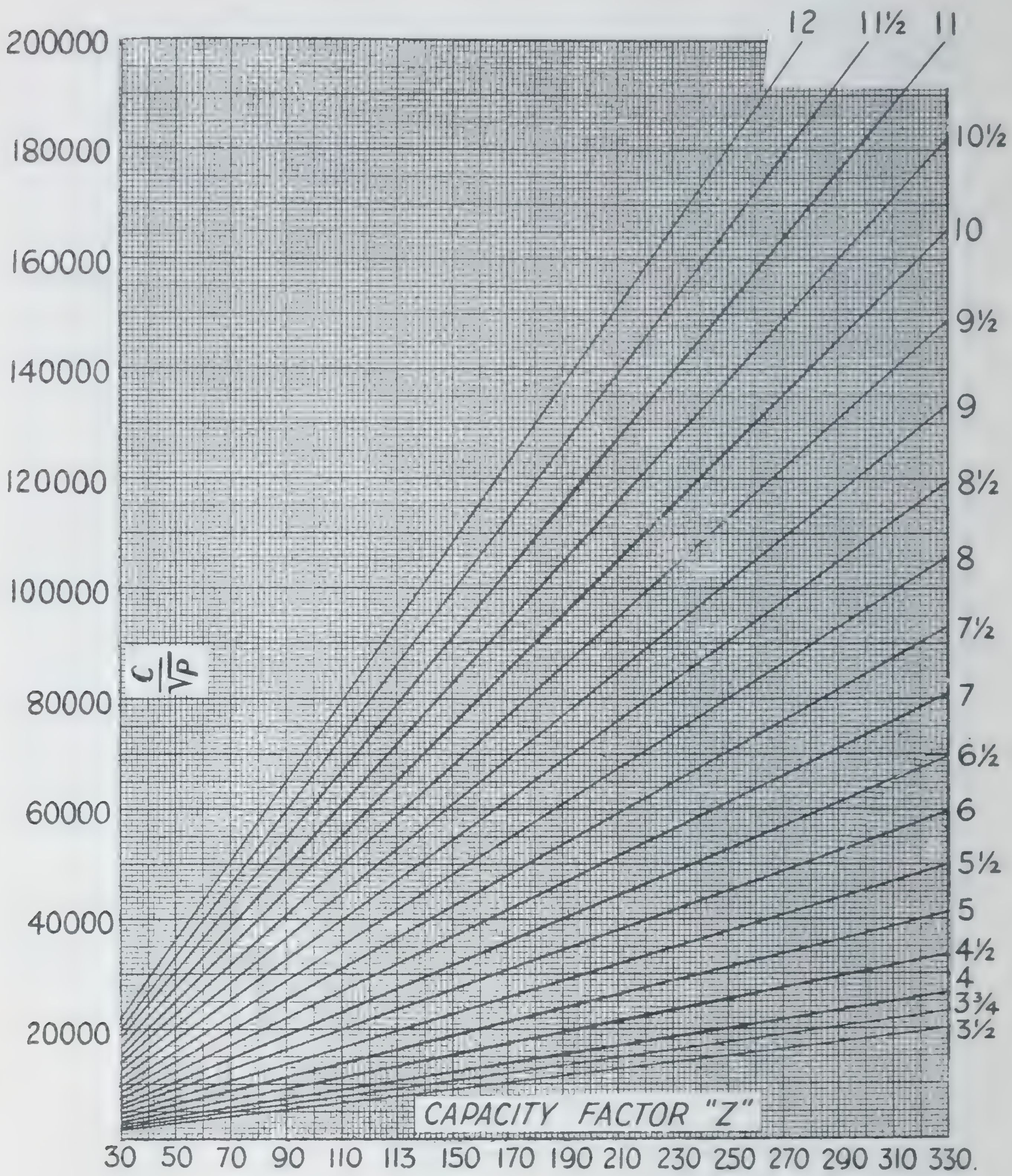

Fig. 3. Standard-Diameter Diagram.

On this diagram, the Z (capacity factor) scale can be changed for other values of $\frac{w}{d}$ by simple arithmetic, the scale changing inversely as the ratio $\frac{w}{d}$. Thus if $w = d$, $\frac{w}{d} = 1.0$, and when compared with Fig. 3, which is based on $\frac{w}{d} = 0.5$, the Z scale should be

half of that shown. Where a Z value of 50 is shown for $\frac{w}{d} = 0.5$, a Z value of 25 would be used for $\frac{w}{d} = 1.0$.

Likewise a diagram may be prepared showing C = cubic feet per minute as abscissæ, $\frac{C}{\sqrt{P}} = \phi$ as ordinates, and P in various values of diagonal lines. This curve is not shown because $\phi = \frac{C}{\sqrt{P}}$ is so readily figured on a slide-rule.

In Fig. 2 are shown Z-E and Z-X curves, which are also based on a Z scale for $\frac{w}{d} = 0.5$.

Since $X = \frac{\pi\, dN}{12 \times 4005 \sqrt{P}}$ we can let $\psi = \frac{12 \times 4005\, X}{\pi} = \frac{dN}{\sqrt{P}}$, whence $N = \frac{\psi \sqrt{P}}{d}$.

This permits further graphical solution by drawing lines for various values of P with dN as abscissæ and ψ as ordinates.

This is shown in the upper part of Fig. 4 with camouflaged scales for ψ and dN corresponding to the marked ψ scale in Fig. 2.

A diagram may also be constructed showing standard values of d with dN as abscissæ and N as ordinates. Such a diagram is shown in the lower part of Fig. 4.

It should be pointed out that for the purposes of this paper no attempt has been made to have the scales for capacity factor Z and dN depict actual fans.

The general use of these diagrams will now be shown.

For solving problems of adjustable-speed fans, C and P being known, $\frac{C}{\sqrt{P}}$ can be computed. A suitable efficiency taken from Fig. 2 fixes an approximate location of Z, and using Fig. 3 the nearest correct value of d is obtained. This, in turn, fixes the value of Z when the $\frac{C}{\sqrt{P}}$ horizontal line intersects the selected d radial line. The value of Z fixes a value of ψ directly above the aforementiond intersection.

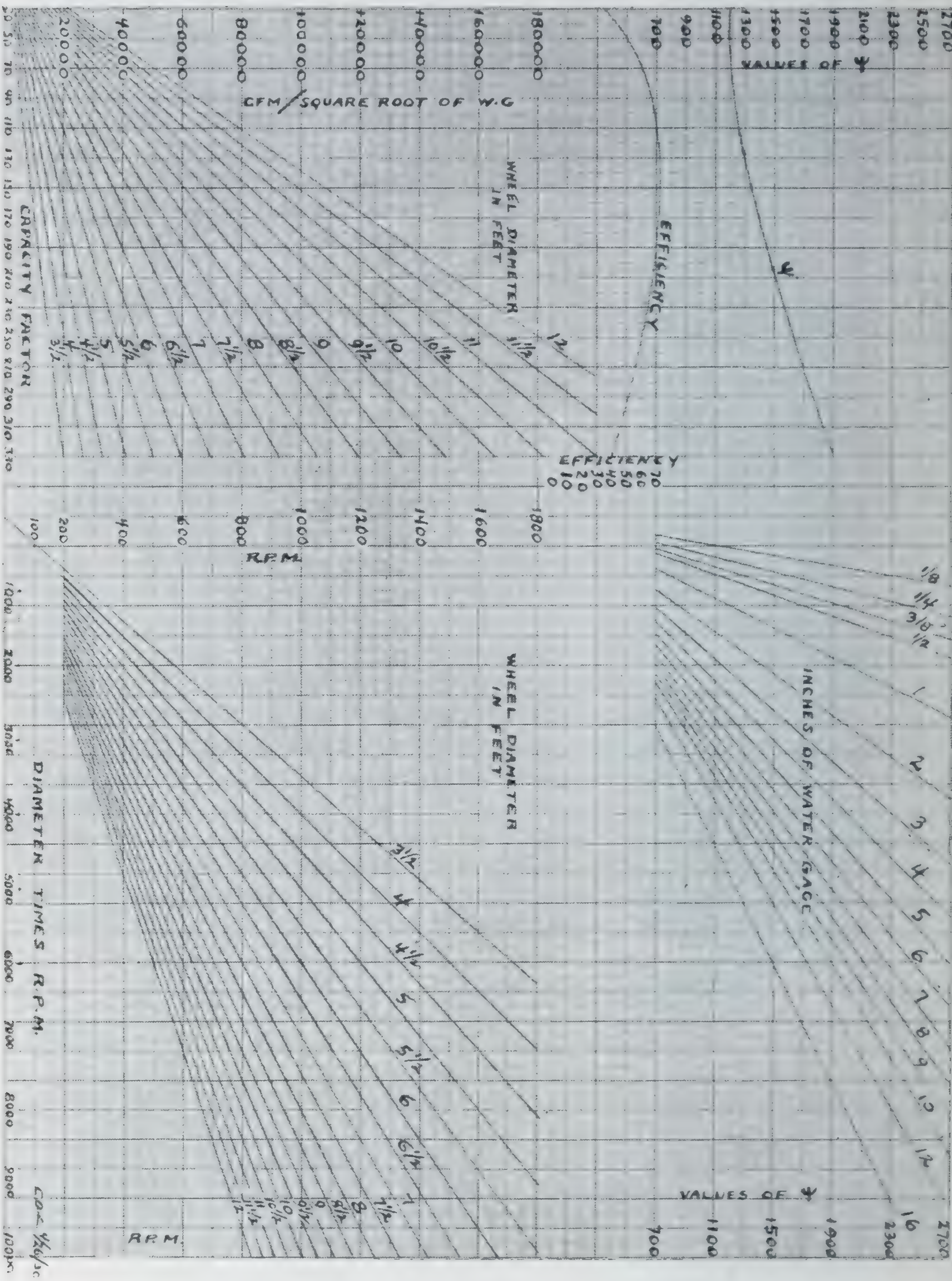

Fig. 4. Chart for Complete Fan Calculation.

In Fig. 4 reading horizontally across from the ψ scale to the required pressure P fixes a value of dN. Dropping vertically down to the chosen wheel, diameter d fixes a value of N which is the required revolutions per minute of a fan of d diameter to deliver the required volume efficiently at the required pressure.

Only a few minutes are required to learn if a smaller fan at higher speed may be sufficiently efficient to be a good purchase.

It is also evident that a rapid selection may be made for a standard fan that would best meet performance for variable service between major and minor values of $\frac{C}{\sqrt{P}}$. In fact, from Fig. 2 and 4, such operation as to efficiency may be seen at a glance and only a few seconds are required to determine the range of speed.

One of the most important features of proper fan selection is to provide for the probable range of actual operating conditions because calculations of air problems rarely suit actual performance.

In order to solve problems of fixed speed, a different procedure must be followed.

From Fig. 3 and 4, it is readily seen that the diameter of the fan must lie between certain limits if good efficiency is to be obtained when delivering volume C at pressure P.

From the determined revolutions per minute, using the lower part of Fig. 4, intersections with the tentatively selected diametric lines, when projected vertically upward to the required pressure line, fix values of ψ.

Values of ψ below the range of the chosen fan design, as given in Fig. 4, indicate that the fans selected are too small.

Having found a fan size that will perform at the given pressure and revolutions per minute, the intersection of the required value of ψ and the Z-X curve locates Z the capacity factor. On Fig. 4, the intersection of the value of Z and the selected fan size fixes the value of $\frac{C}{\sqrt{P}}$ whence C may be determined.

To fulfil the requirement, C must be not less than the specified capacity and as close to this required volume as can be met by a standard fan.

If the specifications are absurd, as many fan inquiries are, it may be expected that speeds will be required that make it absolutely impossible with existing designs to have a proper installation. It is for this very reason that the writer advocates the new diagrams. Engineers having access to such curves would naturally draw better specifications, at least as far as fixed speeds are concerned.

In this connection, it should be noted that proper use of the formula for specific speed based on performance $K = \frac{N\sqrt{C}}{79.72\,P^{3/4}}$ also shows limits of available revolutions per minute to give good efficiency.

The author hopes that fan manufacturers will co-operate with engineers by adopting a standard scale diagram combining the diagrams of this paper. Such a combined chart would enable any engineer to make a quick survey of existing designs and he could select the type or types most suitable for his problem.

This method of engineering analysis would answer the manufacturers' demand for standards. The fan industry would not have to adopt anything radical—simply a convenient graphical solution for fan problems.

Beyond the mere convenience of the graphical solution, there are many desirable features. They are:

Better fan specifications by the purchaser.

More definite comparisons between competitive fans of the same fundamental type.

Gradual elimination of exaggerated claims for performance because centrifugal machines naturally perform as to type.

The development of better fans.

The development of more types of fans thereby giving fan users a broader field from which to select.

Better direction of research work relating to fans.

A clearer picture of the fundamentals of fan application.

A frank recognition of specific speed such as has permitted the great improvement in design of hydraulic turbines and centrifugal pumps.

A simple check of existing installations.

Thus if it be known that a fan of definite proportions is required to deliver a fixed volume at some pressure, the capacity factor Z may be readily computed. From the manufacturer's capacity factor, the relative point of performance is located and it can be seen at a glance whether the fan is too large or too small for the job.

It also would show when standard fans should be replaced by special designs.

The laying out of special fans would become relatively simple. Conditions fix specific speed Design fixes the corresponding ratio, X. The chosen revolutions per minute and required X fix the diameter. Specific speed fixes the efficiency for the design chosen. Therefore, a similar special fan may be readily computed. With a wide range of types and the determination of the effect of changing relative width, it is possible to choose the best combination of type and relative width.

The reader will no doubt visualize many further steps that may be taken to bring the centrifugal fan into place where it will be better understood and more scientifically designed to meet required conditions.

DISCUSSION

D. E. CUTLER:* I think Mr. Carpenter deserves a great deal of credit for the amount of time and work he has put on his very interesting paper, and for the points which he has brought out. I am not familiar with the types of fans which have been discussed here to-night, as my experience has been with centrifugal machines commonly known as turbo-blowers. The general characteristics of the two classes of machines are quite similar and the problems of the manufacturer of fans and the manufacturer of turbo-blowers are very much along the same lines.

There are a few interesting points in connection with designs of blowers. There has been considerable discussion concerning the characteristics of fans with radial, backward-sloping, and forward-sloping blades. The amount of energy which is put into a blower wheel exists at the tip of the wheel principally in the form of pressure energy and velocity energy. The velocity energy should be converted to pressure energy in the most efficient manner. This is accomplished

*Compressor Specialist, General Electric Co., Pittsburgh.

by slowing down the velocity of the gas through discharge vanes or a diffuser passage or some similar arrangement.

The discharge-vane type of conversion results in an efficiency curve which is relatively good at a narrow range, but drops off quite rapidly on both sides of the normal point. Experience has shown us that with the diffuser type of conversion an efficiency curve can be obtained with a relatively wide range of high efficiency. Referring to the characteristics of various kinds of blades, it has been found by experiment that a radial-blade wheel can be given practically any characteristic within certain limits, by changing the design and shape of the diffuser passage.

Experiments have shown that by adding an inlet nozzle of the proper shape to guide the air properly into the wheel, an increase in efficiency is obtained. The elimination of eddy-currents and shock losses also results in higher efficiency. Of course these features all add to the cost and the selling price of the unit. Generally the saving will easily justify the extra expense.

I think the operating engineers can help a great deal by familiarizing themselves with the characteristics which Mr. Carpenter has pointed out and I am sure it would be a real incentive to the builders of blowers to know that desirable operating characteristics and high efficiency would be recognized.

J. F. Barnes:* After the scholarly paper by our distinguished retiring chairman—obviously the culmination of many years of thought and research on this subject—I am a little reluctant to add any remarks about fan application and selection as made by engineers who are not primarily fan specialists. However, many fan applications for manufacturing plants are so made and a brief and humble experience as a fan engineer led the writer to suspect that some applications might possibly have been improved.

I believe you are all familiar with the curves of air delivery, static pressure and horse-power as commonly furnished by fan manufacturers for a given size of a particular style of fan at some specified r.p.m. Perhaps you have even demanded these for one or two sizes and speeds of fan before accepting the fan salesman's proposition. I

*Eljer Co., Ford City, Pa.

show in Fig. 5 a set of curves of this sort which have been prepared for a given size of backward-blade fan directly driven by a 60-cycle motor. This curve has been developed from characteristic performance curves two of which are shown in Fig. 6 for three styles of fans. Now if your manufacturer has given his cubic feet per minute delivery and static pressure in inches of water together with the brake horse-power required, a figure on the fan efficiency may be had from the ratio of air horse-power to brake horse-power. The air horse-power you may obtain from:

$$AHP = \frac{CFM \times TP}{6356} = \frac{CFM \times (SP + VP)}{6356} \quad \text{.......(1)}$$

$$V = 10962 \sqrt{\frac{VP}{w}} \quad \text{.......(2)}$$

In these equations,

CFM = capacity in cubic feet per minute.
TP = total pressure (dynamic) in inches of water.
SP = static pressure in inches of water.
VP = velocity pressure in inches of water.
V = velocity in the fan outlet pipe in feet per minute.
w = weight in pounds per cubic feet of air = 0.07488 for 68 degrees F. and 29.92 inches of mercury.

Equation (1) above is derived from

$$HP = \frac{\text{Weight of air per minute} \times H}{33{,}000},$$

in which H = head in feet of air.

Equation (2) is derived from the law of falling bodies,

$$v = \sqrt{2\,gH},$$

by the simple substitution of conversion values for g, feet per second to feet per minute, and head in feet of air to head in inches of water. The derivation of these will be found in the Standard Test Code for Fans as promulgated by the American Society of Heating and Ventilating Engineers, and the National Association of Fan Manufacturers.

Engineers not intimately working with fans usually do not have available characteristic curves of fans of various types and often but little information for calculating the duct resistances of new lay-outs. For this reason, the selection of the type of fan is usually left to the fan manufacturer. A comparison of the three ordinary types may be had from curves A, B, and C, in Fig. 6. In these I have tried

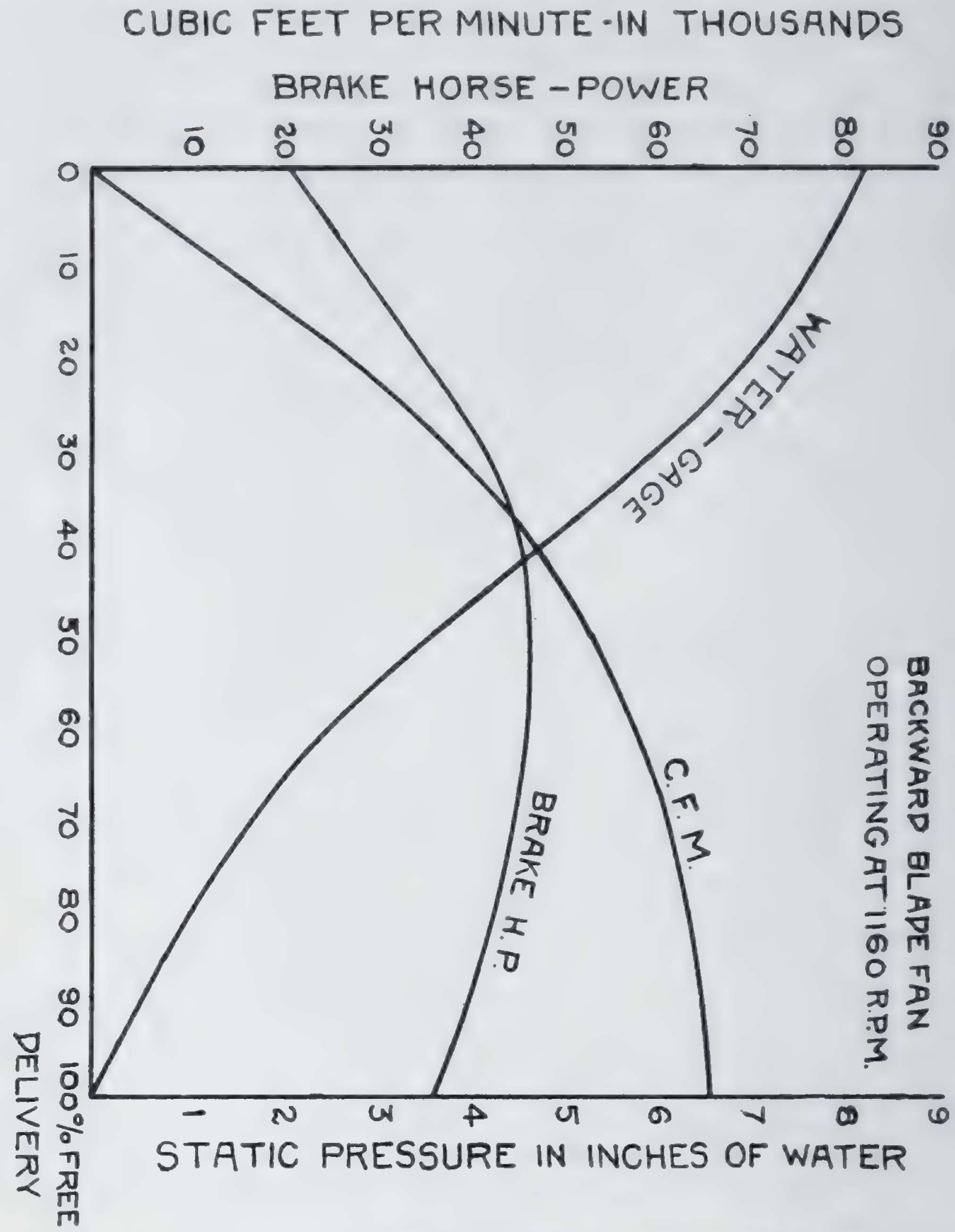

Fig. 5. Curves of Characteristics for Backward-Blade Fan.

to plot the variations in water-gage of typical fans of these three types between the extremes of a completely shut off condition, and 100 per cent. capacity, where the fan is operating at free delivery without duct resistance. The curves of static or water-gage readings are plotted as a ratio to the pressure corresponding to the tip of speed of the wheel. These have been reduced to equal speeds and sizes by the law of similarity or comparison whereby the r.p.m. of similar machines would vary inversely as their linear dimension when running at corresponding speed:

Horse-powers vary as $(\text{r.p.m.})^3$ for the same size.
Pressures vary as $(\text{r.p.m.})^2$.
Horse-powers vary as $(\text{pressure})^{3/2}$.

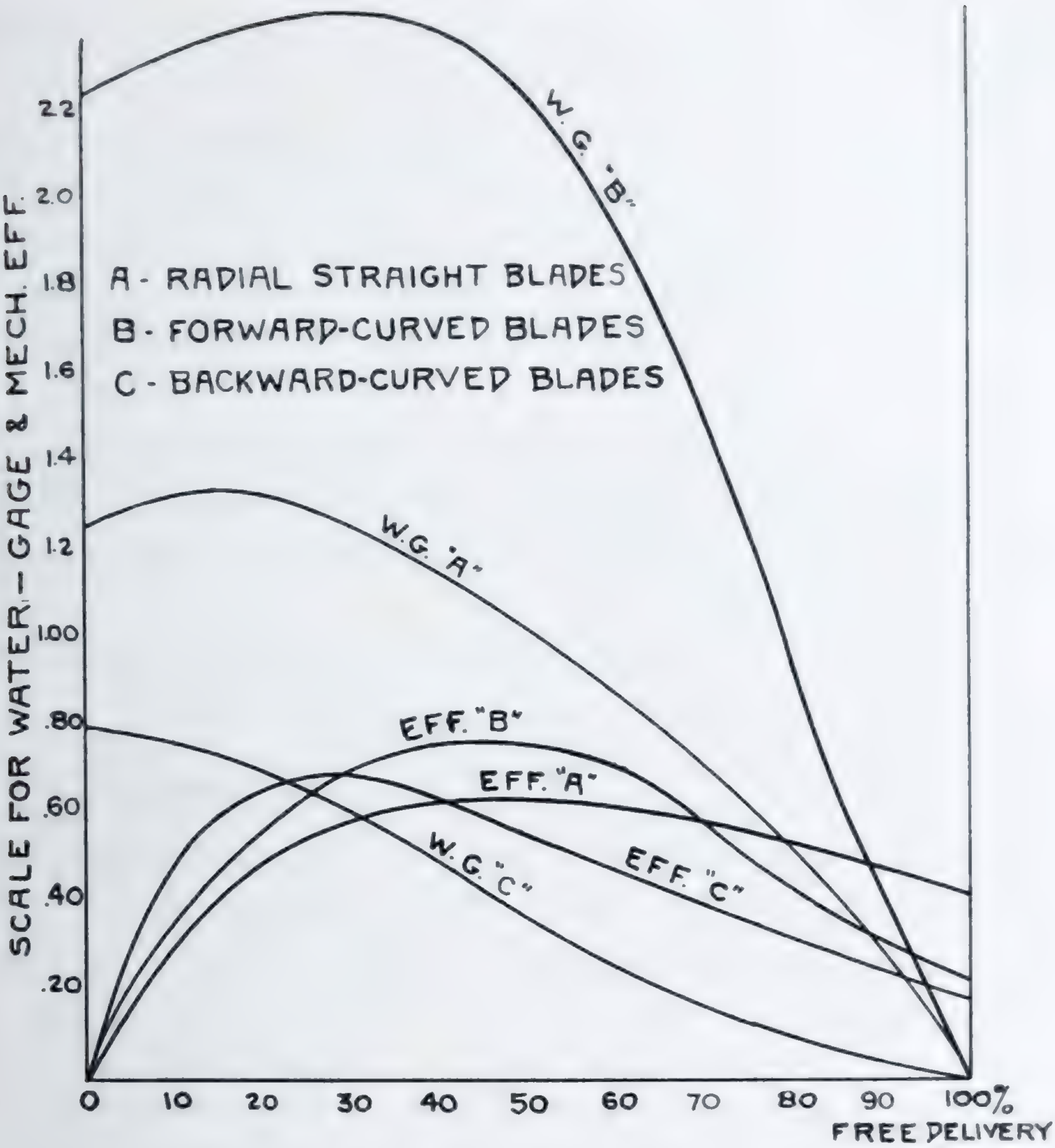

Fig. 6. Comparative Characteristic Curves.

These laws are usually assumed to be accurate for the whole range of performance, and their use allows one characteristic curve to be used for the whole range of speeds for the entire range of sizes where the fans are of similar proportions.

By comparison of the water-gage curves of Fig. 6 it will be noted that for the same point of operation the three fans have radically different pressure characteristics. This means, conversely, of course, that for the same water-gage and operation at the same percentage of free delivery capacity the three fans would have to be run at radically different speeds. Briefly, for operation at the maximum point of efficiency the backward-blade fan C is applicable to relatively high speeds as found in direct drive; the paddle-wheel fan

being applicable to intermediate speeds and the squirrel-cage type being limited almost entirely to low speeds.

Now, from a brief study of the efficiency curves of the three fan types, it is fairly apparent that the best operating range for the backward-blade fan is from 20 to 40 per cent. of its free delivery; for the paddle-wheel type from 40 to 80 per cent. of its free delivery; and for the fan with forward-curved blades, from 50 to 60 per cent. of free delivery.

It is a characteristic of the efficiencies that fans when operating at free delivery do not usually have a very high mechanical efficiency. This is to be expected as housed fans have been designed for operating against a resistance.

As pointed out by Mr. Carpenter, the service of the particular installation in view usually narrows down the choice of fan types due to the limitations of the particular types as regards dust, temperature, fly ash in induced draft, etc. Then again the economies of the particular installation quite often determine the advisability of increasing the investment to purchase higher efficiency through a more complex and higher priced fan or through a larger sized fan of the same type so as to bring the actual performance at a percentage of free delivery which will give a better point on the efficiency curve. In this respect the actual limitations of any of these types of fans may narrowly mark out the selection to be made. For instance, the limiting stress in the reinforcing rings on the backward-blade fans will often limit the maximum rim speed in this fan, thus either definitely limiting the maximum r.p.m. for a particular wheel diameter or definitely limiting the maximum wheel diameter for a given direct-drive motor speed. In ventilation work the problem of silence definitely limits both the maximum rim speed and the maximum air velocity which may be used through the fan outlet. Obviously these values are not the same for the different types of blades or blade angles.

In many cases the fan engineer can rather closely estimate the operating efficiency of any of these types for a particular application (by curves similar to Fig. 6) simply from the efficiency corresponding to the ratio of water-gage (static pressure) to the pressure corresponding to the maximum rim speed of the wheel. In applying the

fan with forward-curved blades to mine work, the ratio of static pressure to pressure corresponding to the rim speed is usually about the best for economy and efficiency. In this work a hyperbolic curve of values similar to Mr. Carpenter's *y* has for ten or eleven years, been used by some of the fan manufacturers in their selection of mine fans, the fan being proportioned by installing empirical values for this and other constants in the *y* formula.

None of the curves shown in Fig. 6 is in any wise new or novel to the fan industry. In fact these are only a few of the many characteristic curves plotted by all of the large fan manufacturers for practically every variation of fan design. Their characteristics vary greatly with special designs of blades and blade angles. Some manufactures include charts of graphical solutions for the more commonly used fans.

I think even a casual study of the efficiency curves in Fig. 6 will show that the selection of a fan for a given installation requires a great deal of care on the part of the engineer if the fan is to operate at or near its maximum efficiency. In practically all the types the efficiency drops off rapidly as the relative capacity decreases below the point of maximum efficiency. It is thus just as bad for efficiency to install a fan which is much too large for the duty required as it is to install one which is much too small. Quite often this latter condition arises from an overestimate of the static resistance of the duct system for the required air delivery. The degree to which it is possible to calculate or approximate the water-gage is in itself a measure of the final efficiency of the fan operation.

It will be realized that for direct drive it may be difficult to select a size of fan which will have a synchronous motor speed fall upon a point at or near maximum efficiency. Then a compromise between several fan sizes must be selected. In doing this an analysis of the change of characteristic of the efficiency curve toward or away from the point of maximum efficiency must usually be made for each of the fan sizes to secure the best fan selection.

This rather lengthy discussion of what may seem like old stuff to the fan men here has been made only because I believe there are many general engineers interested in improving the efficiency of their

fan installations, many of which operate continuously and can pile up enormous power costs.

Perhaps some day fan manufacturers may be able to perfect an analysis of fan blade and volute characteristics which will accurately prognosticate the performance of new blade angles and designs before construction of new fan types. However, no one knows whether such development will come from analysis on a basis similar to centrifugal pumps, hurdling the mental hazard of comparing results with the compressible medium, or whether these developments will come by an analysis of fan characteristics after the graphic and mathematical methods familiar to steam-turbine design analysis. It would not seem difficult for instance to bridge mentally, the easy converse between expansion in the moving blades in a reaction turbine and compression in the blading of a fan with forward-curved blades. Even the jump from a theory developed on expansion as a gas with all its temperature-pressure relation ramifications to a theory for air in centrifugal fans sometimes does not seem as difficult as comparisons using the fluid medium, water, and air.

L. R. Robinson:* There are several things that Mr. Carpenter has explained very well. In volumetric efficiency we have found in several experiments that it varies a great deal. Aside from the different pitching of the blades, the variation of the throat and the width of casing affect this.

C. W. Daubert:† Mr. Carpenter's paper certainly is along the lines on which information is necessary. I want to mention his point that when a fan is to be purchased, it should not be necessary at that time to go into the theory of fan design to be able to sell the fan. The purchaser can not take time to investigate each type and make of fan, and the efficiency of the various shapes and twists of blades, widths, etc.

If the manufacturers could agree on some standard means of testing and showing results whereby we could really get the efficiency and characteristics of fans, it would help a lot in the selection of the proper fan with regard to the size and characteristics which

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†Engineer, American Sheet and Tin Plate Co., Pittsburgh.

are required. We want to know accurately also what a fan will do at one-half, one-third or two-thirds load, depending on operating conditions involved in furnaces or boilers, or whatever the fan application may be. The power question is important in certain installations, but in others it is not so important because you may want certain operating characteristics even at the expense of power.

I can not quite see where you have an ultimate gain in overall efficiency even though you do buy a high-efficiency fan if advantage can not be taken of the efficiency because the duct system will not take the air, or will take too much. We meet conditions like that continually and if the fan maker could stress the point somewhat that it is one thing to get the air out of the fan and another thing to get it to the point where it is to be used, that would help.

Mr. Carpenter is to be commended for his excellent effort to establish a standard method for showing fan performance.

R. R. ROBINSON:* My brother spoke about the changes of throat dimensions affecting the performance of a fan. Some time ago I started testing to determine the relation between depths of the fan throat and its characteristic operation. As yet we have not completed our tests so that I can not give accurate figures showing these effects. However, we do know that not only the volumetric efficiency or capacity of the fan, but also the mechanical and static efficiency are affected. The effects are caused by the changes in area through which the air must pass in leaving the fan.

By changing only the scroll depth, the static and total pressure developed can be changed to such an extent that the specific speed of the fan at various points of operation with respect to the volume delivered, will vary a great deal.

Mr. Carpenter's method of establishing the size of fan used to meet a given condition is the quickest and most accurate method that I have ever seen for determining the actual size of the fan and the point at which the fan must operate with respect to its characteristic curve. But it must be borne in mind that the specific-speed method of calculation requires a special fan for accuracy; and that each design must have its specific speeds tabulated over the entire operating

*Engineering Department, Robinson Ventilating Co., Zelienople, Pa.

scale of that design; and that such a design must not be changed unless the tabulation of specific speeds is changed. In other words, even though the wheel design is maintained in constant proportions, specific-speed tabulations of a certain design will not be accurate unless all dimension relations of the entire fan as a unit are maintained.

With regard to the sealing at the intake of the fan, I think it is largely a matter of commercial economy. I do not know how the leakage of air around the fan intake can be measured accurately except by observing the variation of pressures at the fan outlet when various methods of sealing are used. When elaborate seals are built in fans, the added cost of production is so high, due to the relatively larger sizes of impellers in fans than in pumps, that the gain in efficiency will not save enough power to warrant the expense.

I remember that one of our customers was presented some figures showing efficiencies of 85 per cent. in the operation of high-pressure blowers, and he inquired of Mr. Estep as to the possibility of obtaining such efficiencies. He was told that, from long experience in testing, Mr. Estep had not found many blowers to have an efficiency over 60 per cent. at any point of operation, and that it was unlikely that a commercial blower would be made to perform with an efficiency over 60 per cent. because of the expense entailed in constructing elaborate sealing rings which would prevent recirculation of air from the periphery to the intake of the wheel.

It must be borne in mind that designs are determined by production costs based on manufacturing fans which are generally acceptable. Where fans are stamped, a limited number of dies are used. The limit depends upon demand for the product.

By using the specific-speed method of fixing the size of fan to be used, an exact size of wheel and casing must be built if accuracy is to be obtained. Where dies are used and must be changed for a great variety of sizes, costs become prohibitive.

The question of selecting fans for accuracy is then largely one of economy. The economy may lie in power consumed or in the effects of the operating characteristics on the process for which air must be supplied.

Every engineer, in specifying fans, should consider, then, both the efficiency of the fan, and the nature of the operating characteristics with respect to the character of the process to which it will be applied. Fan manufacturers should be required to submit characteristic curves showing the point at which the fan is designed and the relation between the static and total pressures created by the fan. When the trade demands fans built to exact dimension, and finds it economical to pay the higher price, manufacturers will supply the needs.

C. A. Carpenter: Depending on its design a forward-curved fan normally operates with a volumetric efficiency between 300 and 450 per cent., a backward-curved fan between 100 and 200 per cent., and a radial-blade paddle-wheel fan between 80 and 175 per cent.

Assuming constant wheel diameter and uniform scroll design, wheel and corresponding casing widths may be varied quite widely. When too wide, a fan becomes inefficient due to inlet restriction. When too narrow, efficiency is reduced due to windage and losses through the air passages.

There is no doubt that forming an air seal around the inlets of a fan is advantageous.

The design of inlet seals is governed largely by the required pressure differential. The pressure against which fan seal rings would operate would be very small compared with that of a boiler-feed pump.

Pressure blowers require better seals than low-pressure fans.

I can not state why 70 degrees F. is used as a standard. Not all the manufacturers use it.

Referring to one statement of Mr. R. R. Robinson, it is pretty well known that changes in the scrolls, seals, and other elements of design, have an effect on the performance of any centrifugal machine. It is for that very reason that the fundamental idea of specific speed has taken hold of other types of centrifugal machinery such as hydraulic turbines and centrifugal pumps. Years ago many designers of pumps were designing to meet the ideas of every engineer they met. Each pump turned out was different from any previously built. They finally adopted some of these fundamental

mathematical relations expressed by specific speed and now they work to more or less standardized designs. The fan manufacturers have done the same thing. The point I wish to emphasize particularly in this connection is that a fundamental test must be the basis of design. When design is changed the new equipment must be tested all over again. Once having a design that has been thoroughly tested, fans of differing sizes, speeds, quantities and pressures may be calculated quite accurately.

R. R. Robinson: I did not intend to intimate that the basic design of a fan should be changed for different jobs. Once the basic design is established it must be maintained, all dimensions having constant relations.

C. A. Carpenter: I did not mean to say that the design for every job might mean a change, I wanted to indicate that changes in design mean changes in the relation between specific speed and efficiency; consequently, unless the new design has been tested, accurate predictions of performance can not be made.

There is a great opportunity ahead of the fan industry to develop more types of fans. It may be desirable to sacrifice maximum efficiency in order to obtain higher working efficiency at the actual point of operation. Occasions arise demanding a speed of 1450 r.p.m. Possibly highly efficient fans may be obtained to run at 1150 r.p.m., but some different design would be in order for the higher 25-cycle speed.

Centrifugal pump builders meet almost all set conditions by changes in blading and wheel proportions. Fan manufacturers are staying too close to a few standards.

Mr. Cutler showed that the virtue of the diffusion type of casing is not only to slow down the speed of the air, but also to take care of the higher air angle at discharge so as to prevent extreme eddy losses. It is interesting to note that the General Electric Company recognizes the real problem of air velocities and air angles.

Mr. Daubert brought out an interesting point relative to peak-loads. For commercial success fans should have a broad range of operation at high efficiency.

J. A. Graham:* What feature of design or operation will produce a fan to make the least noise?

R. R. Robinson: The noise developed by a fan in operation will vary with the variation of the pressure-volume relation. When the ducts through which air is passing are straight and unobstructed a hum of a certain intensity and pitch will be evident. If these ducts are obstructed, the pitch of the tone will be raised, or if the obstructions are such as to cause great turbulence, a pulsating noise will be heard. Many mining engineers become so familiar with the constant tone of the fan operation with a certain water-gage that a change in the tone indicates to them a change in pressure in the mine.

The intensity and tone of sound created by a fan are caused by the vibration in the air as it passes from the tips of the blades past the cut-off. If the tip speed is relatively high and the cut-off sharp, and if the velocity through the wheel is relatively high, the sound will be much greater and higher in pitch than is the case when velocities and tip speeds are low. However, tip speeds of fans are determined by three factors, the pressure required, the volume required and the r.p.m. of the fan. Every centrifugal fan has a wide range of speeds at which any unit of that design may be operated to create a certain pressure. So by varying the width and diameter of the wheel, the r.p.m. and tip speed may be changed within the limits of design, to change the noise created; but the actual size will be determined by the limitation of duct sizes.

As a rule the larger the fan and the ducts and the lower the speed, the less pronounced the noise. However, many fans have been destroyed by turbulence in the fan wheels when the fans were too large for the ducts.

There is one more remark I would like to make concerning the backward-curved fan. With blades so designed as to allow the air leaving the wheel to flow in a direction nearly tangent to the periphery, there is the least turbulence and consequently the least abrasion when the air is dust laden. Our experience teaches us that such a condition can be obtained only with a backward-curve type of fan with blades having only one radius of curvature, and that radius the longest possible when using a definite pitch of blading.

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In a large boiler plant, we have three such fans which have operated five years without repairs. These fans handle fly ash, that has an iron content of 12 per cent. An engineer of a prominent steel company told us that he had examined the fans and found them to be in excellent condition.

I want to say a word about the general duct lay-out. I think the majority of those present are interested chiefly in fan application with respect to fan and ducts in units. We have found from experience that in the average duct system the velocity should be from 15 to 20 per cent. of the velocity due to the static pressure desired at the certain point, if best efficiencies are to be obtained.

It is important to avoid abrupt turns unless deflecting plates of proper radii are placed in the turns. A right-angle turn without deflecting plates or curved surfaces to direct the flow of air will consume all the velocity head so that a higher pressure than would be needed for turns of long radii will be necessary in order that the full volume of air will flow. As a rule from 15 to 20 per cent. of the static pressure will be consumed in forcing air through a right-angle turn when no deflection plates or curves in the duct are used.

C. A. Carpenter: In order to make use of the various diagrams clear, I have included in Fig. 4 of the paper, curves which represent no particular fan; also a set of lines representing various fans according to wheel diameters in feet with capacity factor as a base, and cubic feet per minute divided by square root of the water-gage as ordinates. This combined diagram will enable the reader to see how various fan calculations can be made graphically.

With suitable co-operation on the part of fan manufacturers, it would be possible to utilize diagrams of the type illustrated by the author to permit ready comparison of all standard fan designs. Such a procedure would have great advantages in the gradual elimination of faulty designs and the undoubted development of newer types of fans that would permit a wider selection.

WATER-SUPPLY OF A STEEL PLANT*

By T. J. McLoughlin†

Introduction. In summing up the natural and economic factors which determine the geographic location of the steel industry, perhaps the first requirement is an abundant supply of water. I know of no large industry in which the availability of adequate water-supply is more essential. Some idea of the volume of water required can be gained from the fact that it requires from 14,000 to 17,000 gallons of water per ton of steel produced. Also, from the fact that one large steel plant in the Pittsburgh district uses from 100,000,000 to 130,000,000 gallons of water a day.

Intake. The main water intake of a steel plant is one of its most vital points, and considerable care and thought have been given, especially in recent years, to providing against possible interruption in the flow of water through the intake tunnels. Adequate protection against injury through floating debris and ice is imperative. In the Pittsburgh district it is necessary to provide a means for preventing floating material, such as leaves, twigs, ice, etc., from entering the tunnels. In the early days stationary screens were almost entirely used and installations consisted of duplicate screens operating in vertical slots separated by a distance of six to ten feet. These screens could be raised or lowered to remove leaves and ice which would adhere to them. This parallel system of stationary screens had many disadvantages, inasmuch as the raising and cleaning of screens allowed a certain amount of floating material to enter the intake, and made necessary an elaborate system of strainer valves throughout the plant. On rare occasions, when many floating leaves and twigs were encountered, these screens would become choked so that the operation of cleaning was almost impossible. I have known of at least one occasion when it became necessary to blast the accumulations in front of screens to prevent the loss of water in the intakes. With the modern type of variable-speed traveling screens, with which most plants are now equipped, freedom from floating material is assured, the necessity for an elaborate system of strainer valves is removed, and the danger of damage to pumping machinery (if not a complete suspension of production) is reduced to a minimum.

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River Acidity. Another factor, which is especially important in the Pittsburgh district, is the chemical condition of the river water. Since most of the large steel plants in the Pittsburgh district are located on the Monongahela River, it might not be amiss to consider those waters. The character of the Monongahela River varies considerably throughout the year. During the late winter and the spring months, the level of the river is usually high and the water is mostly surface drainage. In the summer and fall, particularly in the case of a dry season, a large proportion of the river consists of underground waters, the impurities of which gradually concentrate when the water falls below pool level. The surface waters of the winter and spring are bicarbonated, and of high turbidity, and contain considerable quantities of floating material such as leaves, twigs, etc.; while the underground waters, because of percolation through pyritic coal-bearing strata, contain considerable free sulphuric acid. The results of typical analyses of the water at the periods mentioned are given below, column A representing the condition when the river is very low; column B, after rain had partially cleared pools of the acid present at the time of sample A; and column C, during a high river. All compositions are in parts per million.

	A	B	C
Volatile and organic matter	5.1	4.3	33.5
Silica	10.6	5.8	9.5
Oxids of iron and aluminium	33.0	5.0	6.5
Calcium oxid	99.0	48.5	35.0
Magnesium oxid	36.9	14.4	....
Sulphuric anhydrid	333.6	110.5	58.7
Chlorin	21.8	10.3	9.0
Free sulphuric acid	92.6	28.8	....
Sodium oxid	....	....	21.2

In order to protect the distribution system from excessive corrosion during the period of high acidity it is necessary to neutralize a considerable portion of the free sulphuric acid with lime, fed either dry or as milk of lime.

Blast-Furnace Requirements. Modern blast-furnace plants are notably large consumers of water. The furnace itself, with its hearth

jacket, tuyeres, tuyere coolers, bosh plate, inwall plates (in some cases only) and cinder-hole coolers, requires enormous volumes. In addition to the furnace proper, the stoves, with their chimney valves, hot-blast valves and valve-seats, burner valves and valve-seats, use considerable quantities. Cinder granulation, pig-casting machines and gas-washing apparatus are additional large consumers. Blowing equipment, power-generating equipment, shops, etc., swell the total demand. This multiplicity of consumers, requiring water at different heads, necessitates a large capital outlay in pumping capacity. Many intermittent consumers and high-pressure water utilizers necessitate individual pumping capacity to supply their requirements. Much of the water needed for furnace cooling is repumped and reused in other parts of the plant, since the average rise in temperature through the system is seldom more than 10 degrees F. A typical example of water requirements for the blast-furnace proper, in gallons per 24 hours, is as follows:

Upper hearth jacket	254,500
Lower hearth jacket	384,500
Tuyeres	488,500
Tuyere coolers	542,700
Hearth plates	
First row	354,500
Second and third rows	430,100
Fourth row	351,400
Fifth row	357,900
Sixth row	354,200
Seventh row	246,000
Eighth row	168,900
Ninth row	160,900
Tenth row	123,500
Eleventh row	116,400
Mantle	112,700
Cinder coolers	149,300
Hot-blast valves and valve-seats	549,000
Stack valves	300,000
Burner valves	276,100
Total	5,766,100

In addition to the above, cinder granulation, pig casting, blowing equipment, cooling and condensing, gas washing and other numerous small items bring the total consumption per furnace up to approximately eight million gallons (excluding condensers) a day. Many of the individual items, such as gas cleaning, pig casting, cinder granulation, vary over wide limits, depending on the equipment used and on purely local conditions; other items have a seasonal variation due to the initial temperature of the water.

Open-Hearth Requirements. The cooling water required by an open-hearth department is used in reversing valves and valve-seats, in stack valves and their seats; in port, bulkhead, skewback, and slag-line coolers; and in gas-burners. All furnaces do not use water cooling to the same extent, since the requirements of a producer-gas-fired furnace are somewhat different from those of a furnace fired by natural gas, coke-oven gas, or liquid fuel.

The volume of water utilized by open-hearth furnaces varies over rather wide limits, depending on the size of the furnace and the character of the fuel used. Variations of from 2,000,000 to 7,000,000 gallons a day have come under the personal observation of the author. For each ton of ingots produced, the consumption in different plants will range from 2000 to 3000 gallons. Those plants which are fired by producer gas require water for cooling purposes at the producer plant. The volume required per producer per hour will vary from 300 gallons, in a modern plant, to as high as 600 gallons per producer per hour in some of the older plants.

In addition to the cooling water required, many plants, especially the older ones, used hydraulic pressures of from 500 to 700 pounds per square inch quite extensively. Hydraulic power is used for spout-crane operation, valve reversing, door operation, tilting of mixers, spotting of mold cars, spotting of hot metal ladles at mixers, etc. The requirements for this purpose—depending on the extent to which hydraulic power is still used—will naturally vary considerably. The consumption per ton of steel will vary from zero to 150 gallons per ton of steel produced.

Blooming-Mill and Billet-Mill Requirements. Water cooling at soaking-pits is usually confined to valves (reversing and stack), and in some cases is used in bridge walls between the pit proper and

the regenerative chambers. The quantity varies from 35 to 50 gallons per ton of steel heated, or about 100,000 gallons a day for a heating capacity of 3000 tons of ingots.

In the mills, by far the largest part of the cooling water is used on the rolls proper, its application being effected through a manifold or trough—located above the top roll in a plane passing through the roll axles—containing nozzles or holes through which the water falls on the roll. The quantity of water used on each mill will vary considerably. A typical installation on the rolls of a blooming-mill showed that 13,000 gallons an hour were used on the rolls. The bearings of this same mill were cooled by six ½-inch sprays and they consumed 3600 gallons an hour. A three-high roughing mill containing seven passes, four of which were filled with steel simultaneously, required 37,500 gallons an hour for cooling of rolls and 8000 gallons an hour for cooling of bearings. A 21-inch, six-stand, cross-country billet mill used 40,000 gallons an hour for cooling of rolls and 18,000 gallons an hour for cooling of bearings. In addition to bearing and roll water, some mills (especially the older types) use water sprays on the pinion necks. Most mills use some water cooling in the form of sprays on the guides. Besides the cooling at the mill housing, certain auxiliary devices such as stamping devices and shear knives require water-jets. As an example of the wide variation in water requirements in some blooming-mills which have come under the author's observation, the variation in consumption of cooling water ranged from 500,000 to 6,000,000 gallons a day. The latter figure was taken from a Mahoning valley plant during the summer months when the water temperature was exceedingly high.

In many of the older mills hydraulic power is used entirely to operate the mill machinery. Operation of soaking-pit valves, covers, pot-car tilting devices, mill manipulators, screw-downs, reversing mechanisms, shears (usually only clutching devices of large shears), tables, transfers, stamping devices, hot saws, etc., is effected by hydraulic power. With such waters as the Monongahela River, which at times carries more than 50 grains per gallon of silt, these hydraulic devices require considerable attention and, during such periods, frequent changes in control valves in order to prevent excessive leakage. On certain finished products, such as sheet bar, it is imperative that the surface be free from scale. In rolling such ma-

terial, high-pressure water-jets are frequently used to cleanse the bars during the process of rolling, and again after the finishing pass to remove the last traces of scale and to cool the bar quickly to a temperature at which little or no scale will form. This operation requires from 30,000 to 50,000 gallons an hour.

Smaller mills rolling reheated material use varying amounts of cooling water for skewbacks, roof supports, skids, charging roll bearings, etc. This quantity will vary with furnace construction from 3000 to 10,000 gallons an hour. For mills of this type, water for cooling rolls and bearings will vary from 30,000 to 100,000 gallons an hour, depending on the type of mill and the number of stands used. Some few mills of this type use hydraulic power for heating furnaces, pushers, small manipulators, and (in the case of three-high mills) for the operation of tables.

Condenser Requirements. The water requirement of the condensing equipment of blast-furnaces and mills is a large and varying amount. In the Monongahela valley the river temperature varies between 32 and 85 degrees from winter to summer, so that in the condensers which, with one or two exceptions, are of the barometric or jet type, the water requirement will vary considerably. Some idea of the volume necessary can be obtained from a statement that the steam-driven prime movers—which, because of location and grouping, can be operated condensing in a plant producing 4500 tons of ingots (with the corresponding quantity of pig-iron)—require about 20,000 generated boiler horse-power.

Boiler Feed-Water. The boiler feed-water requirements of a steel plant bear no fixed relation to output, but depend on type rather than weight of production, nature of prime movers employed, and degree of concentration of power-generating capacity. The waters of the Allegheny, Monongahela, and Ohio rivers, which are the source of supply of boiler, as well as cooling water, contain scale-forming impurities which must be removed in order to meet, successfully and economically, the steam demands of the industry. Since the waters of these rivers are not particularly well adapted for surface condensers, the generating of steam is almost entirely done from treated river waters.

Steel plants having a steam demand of 25,000 to 35,000 boiler horse-power are numerous and the boiler feed-water requirements are large. Since the conditioning of feed-water is the subject of a later paper at this meeting, I merely mention some of the methods now in use in the district.

Some few smaller plants are using a hot lime-soda process; some are using continuous, cold lime-soda treatment; some are "zeolite" plants; but most of the treatment is by an intermittent lime-soda process followed by filtration of the gravity or pressure type. Internal boiler treatment, which has in recent years been the subject of intensive study, is rapidly being recognized and utilized as an economical and effective method of preventing scale formation and reducing the cost of steam generation.

I have prepared and reduced to graphical form a typical distribution sheet for the water in a modern steel plant. This is shown in Table I. All figures are in gallons per day and the conditions are those of a typical steel plant producing daily 3000 tons of ingots. This table is based on figures obtained entirely from plants in the Pittsburgh district and, perhaps, more strictly representative of practice in this section than in the more eastern, southern, or western steel-producing centers. The problems of these communities I have not attempted to cover, since it would require more time than that allotted for this presentation. The Illinois-Indiana and the Buffalo districts, with their lake waters, are probably most highly favored from the standpoint of quality and quantity; the southern district is favored from the standpoint of quality, but often sorely pressed from the angle of volume; the Mahoning valley is rather poorly favored both as to quality and quantity.

The wide variation in volume encountered in studying the consumption of various plants is due to purely local conditions, and to the desire of operators to be sure of an adequate supply of water passing through cooling devices and over surfaces to be protected. Pumping costs vary from one-half cent to one cent per thousand gallons and interruptions to steel-mill operation are extremely expensive, so that economies in water consumption, which must be small, effected at the risk of mill delays, are never considered.

Any discussion of either type or unit of pumping machinery, has been purposely omitted, since peculiarly local conditions and wide

TABLE I. WATER REQUIREMENTS OF TYPICAL STEEL PLANT

Cooling of furnaces and stoves 5,500,000 Blowing-engines (jet condensers) 4,340,000 Gas washing 3,300,000 Miscellaneous 200,000		1 furnace blown by reciprocating steam-engine 13,340,000	3 blast-furnaces (2100 tons a day) 43,767,000	total requirements of plant 82,695,000
Cooling of furnaces and stoves 5,500,000 Blowing-engines 644,000 Gas washing 3,550,000 Miscellaneous 200,000		1 furnace blown by gas-engine 9,894,000		
Cooling of furnaces and stoves 5,500,000 Turbo-blowers (surface condensers) 12,338,000 Gas washing 2,120,000 Cinder granulation 375,000 Miscellaneous 200,000		1 furnace blown by turbo-blowers 30,533,000		
Jet condensers 15,000,000 Miscellaneous 105,000		power generation by 15,000-kilowatt turbo-generator 15,105,000		
Hydraulic 548,000 Cooling and miscellaneous 102,000		Bessemer 650,000	steel production (3000 tons a day) 6,960,000	
Furnace cooling 3,600,000 Producers 210,000	4 furnaces, producer-gas fired 3,810,000	open-hearth furnaces 6,310,000		
Furnace cooling 2,400,000 Hydraulic 100,000	5 furnaces fired by tar and coke-oven gas 2,500,000			
Soaking-pits 105,000 Rolls and bearings 501,000 Hydraulic 363,000	blooming-mill 969,000	rolling-mills 13,863,000		
Jet condensers 1,340,000 Rolls and bearings 1,030,000 Hydraulic 4000	roughing mill 2,374,000			
Jet condensers 1,380,000 Rolls and bearings 1,520,000 Hydraulic 342,000	rail-billet and sheet-bar mill 3,242,000			
Jet condensers 1,730,000 Rolls and bearings 815,000 Hydraulic 9000	continuous billet mill 2,554,000			
Furnaces 511,000 Rolls and bearings 4,038,000 Hydraulic 175,000	5 merchant-bar mills 4,724,000			
Treated boiler water 3,000,000				

variation in demand preclude even the most sweeping generalizations. Since the production rates of various departments of a steel-mill are always carefully co-ordinated, continuity of operation is most essential. Prime movers driving pumping machinery are always so chosen that the possibility of interruption of water-supply is at a minimum.

DISCUSSION

EDWARD A. BROWN, JR.:* In making a study of water-supply for the steel plant, I believe at the present time one of the items of most importance is the thorough application of the principal of reuse or recirculation.

In most of the applications of water for cooling purposes, the temperature is immaterial and the temperature rise is usually low. For instance, the circulating water in blast-furnaces usually rises from but seven to ten degrees F., and this water after passing through the furnace coolers is just as good for further cooling as it was initially, there being no reason why it could not be used two or three times. The question, then, immediately rises, as to why a smaller quantity of water is not used in the coolers and the temperature increased until the discharge temperature is so high that it would be economical to pass it to the sewer. This question is fundamental where many industrial plants are provided with an acid water, possibly carrying considerable mud. As soon as an attempt is made to throttle the water by valves in the inlet, either mud clogs up the valves; or scale, which is formed in the pipe due to acid corrosion, etc., flakes off and plugs the valves and there is only one safe way to operate coolers under such conditions and that is to let them flow full, for while this much water is not needed, it is probably essential in order to keep the water flowing.

The only way, then, to maintain a free flow and obtain a sufficiently high discharge temperature is either to pass the water through a series of coolers connected in series on the initial pressure head, or utilize the initial pressure head in a high series of coolers and then pass to equipment which requires a lower head, and so on; finally, if possible, using all or part of the water for some purpose where heat is actually an asset, such as for boiler feed-water where the tempera-

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ture is not only an economy in fuel, but an aid in treatment. In the above process it may be necessary to collect and repump the water at some intermediate point, but at a point considerably above the initial head where the difference between initial head and collecting-point head represents gain.

To be more specific, water may be pumped from the initial source through a surface condenser at sufficient head not only to overcome the condenser resistance, but also to raise it to the highest point required, and, for the present, we will assume this to be blast-furnace coolers. After passing through these it may still be sufficiently low in temperature to serve the purpose of some low-vacuum, barometric-type condenser, many of which still exist in the steel-mills; or it may be used with a partial boosting for gas-washing purposes, cinder granulating, etc. A portion may first be shunted off for boiler feed-water use. Even though this may not be possible throughout the entire year, it probably would be for six months when the water varies from 34 to 50 degrees initial temperature.

I believe what has been suggested should be given thorough consideration in connection with the water-supply for steel plants.

H. B. Mann:* The vital necessity of reliability in water-supply mentioned by Mr. McLoughlin is a limiting factor in determining the size of pumping equipment. However, the increased demand of the mills for water has tended toward larger units. The reliability of such units has been increased with experience in building large turbine pumps. The advantage of the large unit is not primarily economy but saving in space in pump houses which are quite expensive and in the ability to get increased capacity into present pump-house buildings.

In view of the wide range of pressures used by the various mills it would appear that economies might be effected by a careful study of distribution systems. In some cases the use of booster pumps to points where higher pressures are required in the mill rather than using the high pressure throughout makes a considerable saving in cost of pumping on account of the lower head for the general system and also because, at the lower pressure, less water is wasted.

As to the deterioration of cooling pipes when the water is used at high temperatures it can be said that de-aërating of water has

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become quite a simple process and is done in simple equipment with very little change in temperature or heat content. It is just possible that in some cases de-aëration might solve some of these problems.

O. P. ADAMS:* I want to ask Mr. McLoughlin if he knows of any study that would indicate the proper point to which it is desirable to reduce the acidity of mill-service water by the addition of lime. The cost of lime for reducing the maximum allowable acidity in the mill water from two grains to 0.5 grain per gallon, for example, amounts to quite a large sum of money in a year in those plants located on the Monongahela or Youghiogheny rivers, and the reduction in maintenance expense due to the lower maximum acidity would have to exceed the cost of the additional lime to justify the procedure. Some laboratory tests were conducted by our company, and these indicated that on pipe material the difference in the corrosion rate of water containing two grains of acid per gallon and that containing only 0.5 grain per gallon was very slight, and that the higher corrosion rates occurred with an acidity higher than two grains per gallon. In these tests, however, the velocity of impact of the water against the test sample was much lower than, for example, we would have around the disk of a throttle-valve. The protective effect of mineral and vegetable deposits and oxids is apparently very great, and as this protective coating is removed or inhibited by high-velocity impact, we doubt if the corrosion rate found in our test represents the condition actually existing in the valves and fittings of our water systems. We would be interested to know of any other research work along these lines.

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WELLS AS A SOURCE OF INDUSTRIAL WATER-SUPPLY*

By F. Thorpe†

Modern methods of efficiency in machinery and management have made themselves felt in well drilling. Instances without number can be cited where the underground water found in sand, gravel, or sand and gravel formations has been abandoned because of difficulty in maintaining a reliable, efficient well.

The following evolution or development of wells is to be considered:

1. Perforated-pipe wells.
2. Small-diameter, metal-strainer wells.
3. Gravel-packed, large-diameter, metal-strainer wells.
4. Gravel-packed, slotted concrete wells.
5. The porous concrete well.

Pipe wells usually consist of iron or steel pipe driven into the ground with the lowest ten to fifteen feet perforated by drilling holes in the casing. This well produces small volumes of water, due to its limited size and the small amount of open area of strainer. It is subject to corrosion, and also to closing up of the holes if too small, by the deposit of chemicals found in all well water, such as the carbonates of iron. When this type of well is called upon to deliver capacities in excess of 100 gallons a minute, the water velocity through the holes in the casing is so great that sand comes into the well, eroding any type of pumping equipment used. Where large quantities of fine sand are removed, the well may develop a sand lock, in which case the sand itself shuts off the suppiy of water.

Small-diameter, metal-strainer wells are subject to the same conditions, but, due to the ability of the well driller to select more carefully the size of the holes or slots in the strainer, it is possible to secure a slightly better performance than is obtained from the perforated-pipe well.

The gravel-packed, metal-strainer well of large diameter is the first large-capacity well developed. The largest well of this type con-

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sists of a metal strainer 24 inches in diameter and from 10 to 50 feet long which is surrounded by a pack of gravel usually six inches thick. It is the purpose of this large diameter and gravel pack to expose as many square feet of water-bearing material as is possible with this type of construction. Wells of this type are capable of producing from 500 to 2000 gallons a minute, provided the natural formation is suitable. The capacity of this type of well is determined by the amount of water which can come through the strainer by lowering the water in the well with a pump. The main disadvantages of this type of construction are:

1. The strainer itself is subject to corrosion.

2. The chemicals found in all well waters are attracted by and deposited on the strainer, and will in time completely close the openings.

3. Due to the relatively small open area of the strainer in comparison with the volume of water taken out, the water velocities are so high that sand comes into the well; for instance, in a well having a strainer 24 inches in diameter and 25 feet long, the total external area of the strainer will be approximately 160 square feet, and the total open area of the strainer will not exceed 16 square feet. The high water velocities caused by this restricted area, and the accompanying frictional losses, must be overcome by increasing the difference between the static water-level in the well and the water-level in the well when pumping, which factor is called "draw down," for convenience.

In the gravel-packed, slotted concrete well it is possible to increase the length of the strainer so as to make it the full length of the water-bearing stratum, and at the same time provide a strainer material which is unaffected by corrosion and will not attract the deposit of iron carbonate. The maximum diameter of well possible in this type is 32 inches. This type of construction increases the total open area of the strainer to approximately 60 square feet for each hundred feet of slotted casing installed. While this type of construction permits a greater total open area than is possible with the metal-strainer well without increasing the cost of installation, the average water velocity at the periphery of the strainer is in excess of the critical velocity; and, further, the water velocity through the slots is high enough to

produce considerable friction and a resulting increase in "draw down."

The porous concrete well casing is 36 inches in outside diameter, and 26 inches in inside diameter. It is made of carefully screened angular gravel and cement in a manner which does not sacrifice its strength. With this construction it is possible to obtain a total open area equal to 30 per cent. of the external area of the porous concrete casing, which compares favorably with the eight to ten per cent. possible in slotted concrete casing, and the five to ten per cent. possible in the metal-strainer construction. Being made of concrete, it has no attraction for iron carbonate under water. The following figures are taken from a well installed for the city of Dover, Tuscarawas County, Ohio, which is 102 feet deep. The first 26 feet below the surface are cased with impervious concrete sections of the same size as the porous concrete casing. The rest of the well consists of 19 four-foot sections of porous concrete well casing 36 inches in outside diameter. On test, this well delivered 1500 gallons per minute with a "draw down" of six feet. The figures compare a porous concrete well and a slotted concrete well, each of the same total depth and same strainer length.

	Porous concrete well		Slotted concrete well
Outside diameter of casing in inches	36		24
External area of strainer in square feet	717		477
Porosity of casing in per cent	30		7.58
Area of openings in strainer in square feet	215		36
Ratio of open areas	6	to	1
Average velocity of water at periphery of strainer in inches per minute	3.36		5
Ratio	2	to	3
Water velocity through open area in inches per minute	11		66
Ratio	1	to	6

From these figures the friction caused by the strainer of the slotted concrete well is evident by comparison of the water velocities developed. In the porous concrete casing the velocity of water

through the pores of the casing is but 11 inches per minute, whereas in the slotted concrete construction the water attains a speed of five feet six inches per minute. This high velocity of the water through the concentrated inlet slots makes itself felt outside of the gravel pack in the manner of an inverted jet. For this reason, wells of slotted concrete construction pump sand. Furthermore, due to the restricted strainer openings, the "draw down" is usually two or three times that of the porous concrete well.

The porous concrete well with its thousands of small holes evenly distributed over the entire surface of the exterior of the well strainer, which makes the concentration of flow at any one point impossible, together with the low average water velocity at the periphery of the strainer and the low water velocity through the openings in the strainer, precludes all possibility of the well developing sand under normal conditions of capacity. It is, of course, possible to force the porous concrete well to pump sand, but to do this in the well at Dover, Ohio, it would be necessary to raise the average water velocity at the periphery of the strainer to a point in excess of nine inches per minute, which would require that a capacity in excess of 4000 gallons per minute be withdrawn from the well. This clearly illustrates the ability of the porous concrete well to deliver the greatest quantity of water possible per well unit without excessive "draw down" and without the pumping of sand. It might be added that the official test of the water from this well (by the state of Ohio) showed the turbidity to be zero, proving conclusively that porous concrete wells deliver water entirely free from all suspended matter.

Outstanding installations of this well can be found in the following places:

At Newell, W. Va., is installed a porous concrete well 80 feet deep with the static water level 38 feet from the surface. This well has been tested to a capacity of 2250 gallons per minute, at which capacity the "draw down" was ten feet six inches.

A refinery located at Wood River, Ill., has a total of 11 porous concrete wells, out of which they are taking over 16,000 gallons of water per minute. These wells were installed over a period of eight years, and all are still in active service. It might be stated at this

point, that the oldest well, now eight years old, is still producing 1500 gallons per minute.

At an industrial plant in Muskegon, Mich., a porous concrete well is producing 350 gallons per minute. This well is installed in very fine lake sand. This capacity is five times the amount taken out of any competitive large-capacity well ever installed in this plant, where all gravel-packed wells failed because of sand being pumped. The porous concrete well in this place has continued to deliver its rated capacity of water free from sand over a considerable period of time.

At Granite City, Ill., a porous concrete well is installed. The only water-bearing stratum in this well is a vein of quicksand 36 feet thick below water-level, and 76 per cent. of this quicksand will pass through 100-mesh screen. This well develops a capacity of 1000 gallons of water per minute free from sand.

At Alton, Ill., a porous concrete well was installed to replace five small metal-strainer wells. It produces 1250 gallons per minute, which was the total capacity of the five abandoned wells. Due to the high efficiency of the new well, it is possible to pump 1250 gallons per minute against the desired surface pressure with a 40-horse-power motor. When the five small wells were used it required five 25-horse-power motors, all fully loaded, or a total of 125 horse-power, to produce the same quantity of water at the same surface pressure.

The use of well water for cooling purposes, particularly in the condensers of turbo-generator sets, is attractive. In this application it is possible to furnish clean, cold water at a temperature of 56 degrees F. to the condenser with a definite increase in the vacuum obtained. Furthermore the tail-water temperature of the condenser is still low enough for the water to be used again for general plant service. The temperature rise occasioned by the condenser does not cause precipitation of any of the hardness in the form of scale, keeping the condenser-tube surfaces clean and in the best condition for most efficient operation. Supplying clean water to the condenser, instead of the usual turbid river water, eliminates the necessity of frequent condenser cleaning.

The preliminaries necessary to the installation of a large capacity well of the porous concrete type are:

1. Location. It is possible to install this type of well along glacial rivers or rivers draining in glacial territory, such as the Allegheny and the Ohio; also, in valleys which are filled with glacial deposit or drift, such as are found in northwestern Pennsylvania, and the greater part of Ohio.

2. A test hole should be driven to rock or to a sufficient depth to ascertain the presence of sand or gravel. These samples should be taken in as near their natural state as is possible, for with this information it is possible to figure the capacity of a well installed in the location of the test hole.

3. The samples are submitted to two tests. The first test is to ascertain the water velocity required to move the smallest particle of sand in each stratum encountered. The second test is to determine the amount of water which will flow through the sample with an imposed head equal to one foot of water. With this information, together with the static level of the water in the ground and a rough survey of the underground water-storage basin, it is possible to determine the capacity of the well. This makes it possible to approximate the "draw down" in the finished well, thus determining the greatest amount of water which can be taken from a well installed in the location of the test hole.

In installing the well, steel temporary casing is used to the water-bearing formation—first, 10 feet of 60-inch diameter; second, 25 feet of 54-inch diameter; third, 45-inch diameter casing to the proper depth. The material within the casing is taken out by hand or by an orange-peel bucket. Into this excavation is lowered the first five or six concrete well sections, which are assembled on a steel cutting edge and held in position by four through rods fastened securely to the cutting edge, and passing through four 1¼-inch vertical pipes cast in each concrete well section, these rods being grouted in with cement and sand. Each tongued-and-grooved joint is grouted in a similar manner. Additional well sections are then assembled on top of those already in the well until there are two or three sections above grade. By a set of cantilever pressure beams additional pressure is placed on the well sections. The sand and gravel is then removed by sand pumping with a large bailer. As the material is removed from inside of the well casing, the weight of the casing plus the

additional weight added by the pressure beams is sufficient to force the casing into the water-bearing formation. As the casing is forced into the ground, additional sections are added until the desired depth is obtained. Five ⅛-inch deformed steel rods are placed in the 1¼-inch diameter pipes throughout the total depth of the well and securely grouted in with cement and sand. After all well sections have been installed, a solid concrete plug is poured in the cutting edge. The temporary steel casing used to facilitate the installation of the well casing is, of course, withdrawn, and the excavation is backfilled.

The well is now complete and ready for the installation of pumping machinery. Due to the extremely low water velocities encountered, no sand can come into the well, and after the dirty water which was inside of the well casing during the sinking operation has been removed by a pump, the water clears and remains clear for the life of the well.

In conclusion, the porous concrete well offers freedom from carbonate deposit on the strainer, clear water free from sand during the life of the well, greater capacity per well unit, reduced cost of water, highest efficiency of well, and longer life of well.

DETERMINATION OF MECHANICAL PROPERTIES OF STEEL*

By R. L. Templin†

Mechanical Properties. So much information on the mechanical properties of steel is available in the technical literature, that it would seem unnecessary to discuss the definitions of the various properties and the significance of each. It may be pointed out, however, that there must be agreement on definition of what is meant by such terms as tensile strength, yield-point, ductility, etc., before we can adequately discuss ways and means for evaluating these properties of any material. The reader is referred to the proceedings and standards of the American Society for Testing Materials for definitions of these mechanical properties. In what follows we shall give consideration primarily to the more common mechanical properties such as tensile strength, yield-point, elastic limit, proportional limit, ductility, hardness, impact, torsion, and fatigue. We shall, furthermore, confine our discussion to the determination of values for these various properties at normal temperatures. Because of the information which is available on the subject, a certain amount of repetition of facts is scarcely avoidable but experience would indicate the necessity of repetition for the purpose of emphasis to the end that better testing will be accomplished.

For a steel, fabricated in a given manner and subjected to a given heat treatment or in some cases a range of heat treatments, there appear to be definite relationships between some, if not all, of the mechanical properties of the steel. Once these relationships have been established, it is frequently quite easy to evaluate the different mechanical properties of various lots of similar product by the actual determination of only one or two values of the mechanical properties. This fact is regularly made use of in the routine inspection testing of steel products of various kinds. Unfortunately, this procedure if carried to extremes will frequently lead to serious errors or unsatisfactory results. For example, consider the relationship shown in many cases to exist between the tensile strength and the Brinell hardness of steel. This relationship is generally expressed by an equation of

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the form, $T = BK$, in which $T =$ the tensile strength, $B =$ the Brinell hardness, and $K =$ a constant.

Now the value of K is usually in the neighborhood of 515, with the result that any errors made in the determination of the Brinell hardness are multiplied by 515, thus causing appreciable errors in the values for tensile strength. Conversely, knowing the tensile strength of a steel and the proper value of the constant in the above formula we could determine the Brinell hardness by a simple calculation, within very close limits.

Relationships between mechanical properties of steel are not only useful in the inspection of final products but are frequently of considerable assistance in choosing design stresses for structures or in determining the suitability of a steel for a given purpose. Two relationships commonly used in this manner are the ratio between yield-point and tensile strength, and the ratio between endurance or fatigue limit and tensile strength.

Methods for Determining the Properties. The size and shape of test specimens used in determining the mechanical properties of steel must be given much consideration because the test values obtained are usually functions of both these factors. This was realized early in the history of testing metals, and so, in order that results from different sources might be readily comparable, it became necessary to adopt specimens of suitable sizes and shapes. The choice of size and shape of specimen, however, is often influenced by other factors such as precedent, character of product, method of preparation, type or size of testing apparatus, and preference or whim of some individual or group of persons.

The so-called standard specimens used in testing metals, therefore, are of dimensions more or less arbitrarily chosen, generally in agreement with the ideas of those concerned with using such specimens. One of the earliest successful attempts at standardization of a tensile-test specimen for metals occurred in the eighties in Germany. A group of pioneers in the scientific study of the properties of metals, including Martens, Bauschinger, and Tetmajer, were wont to get together at intervals to discuss the results of their findings. Upon being convinced that size and shape of specimen affected the tensile properties of metals, Martens reported, "For this reason it was soon

agreed, either quietly or upon consultation, to adopt definite dimensions for the gage-length (l_g). At the present day [1898] the gage or standard lengths of 8 or 4 in. are in common use in industrial countries, the most generally adopted length being 8 in. (= 20 cm.)".

In spite of all the research work that has been done with regard to size and shape of specimen, these factors must still be considered in our present-day test results. In the case of the tensile-test specimen used in this country where it is customary to use a fixed gage length and a variable cross-sectional area, we find that the elongation and reduction in area (that is, the ductility) are appreciably affected by these factors. The Rockwell, Brinell or sclerescope hardness values are considerably affected when thin specimens are used. In the case of fatigue tests of cast-iron, marked differences in the values obtained are observed by using different diameters of rotating-beam type of specimens. The discrepancies in the impact values obtained on steels using various types of notches are generally recognized.

From these facts it is quite evident that the mechanical properties which we determine are not only a function of the material being tested, but also in many cases are very much a function of the specimen used and, as we shall see later, of the actual testing procedure followed. Theoretically there may be "true" values for the various mechanical properties of a given material, but practically such values can not be determined, at least on a routine commercial basis; and in many instances it is very doubtful whether or not they can be determined with the best apparatus available to-day, used under optimum laboratory conditions.

As long as all parties concerned use the same test specimen and the same testing procedure for determining a mechanical property of a given steel, satisfactory understanding will obtain. Difficulties arise, however, when attempts are made to use this same specimen and testing procedure for other types and grades of steel. For example, the tensile-test specimen commonly used for boiler-plate is not satisfactory for use in determining the tensile properties of hardened high-carbon or other alloy steels. In addition to the difficulties in preparing the large specimen from hardened steels, the ordinary testing machines would not grip such a specimen satisfactorily, so we are obliged to change the size and use a different shape of specimen.

The tensile-test specimen used for hardened alloy steels is usually of the round, shouldered-end type with a short gage length (two inches) and comparatively small cross-sectional area; yet comparisons are often directly made between the mechanical properties obtained with such a specimen and those obtained from tests of mild steel using the much larger specimen.

The product from which specimens are taken may, and often does, govern to some extent the size and shape used. This is best exemplified in the case of thin sheet metals as well as plate wherein the thickness of the specimen is the thickness of the material being tested. This practice which is virtually standard in this country, gives us a different size and shape of test specimen for every thickness of the material, making it very difficult in some cases to make satisfactory comparisons of the values obtained for the mechanical properties.

When recourse is had to the use of various sizes of round specimens with dimensions such that geometrical similitude obtains throughout, more accurate comparisons of mechanical properties can be made. Objections to such a procedure are based primarily on the fact that such specimens are often expensive to prepare; testing machines of suitable capacities for handling such a variety of sizes are not available in all laboratories; and such specimens do not give as accurate an index of the properties throughout the section of the product from which they are cut as do the larger specimens which include the total thickness or cross-section of the product. In general, a better idea of the properties of the product will be obtained by the use of a number of small specimens cut from various parts of the product rather than by the use of one or two large specimens which include the total thickness or cross-section of the product.

Assuming that the size and shape of specimen for a given product have been agreed upon, it is customary to expect such a specimen to give certain values of mechanical properties irrespective of the portion of the product from which a specimen is taken. Those familiar with metal products, however, realize that there are differences in the values of mechanical properties, depending on the location from which the sample or test coupon is taken. These variations are the result of the fabrication practice used and, while generally undesirable, yet are usually unavoidable because of the current knowledge

in the art of fabrication of the product. The practice of taking test samples from trimmings and cropped ends is sometimes followed. Coupons attached to forgings or castings, or separately produced coupons, may and often do give values appreciably different from those which would be obtained had the specimens been cut out of the finished product. A satisfactory solution of such difficulties would appear to lie in the recognition of the fact that such differences are likely to obtain, but an attempt should be made to determine their magnitude so that the test values obtained, from a given specimen taken from a definite location with respect to the product (as agreed upon by all concerned), will serve as a satisfactory index of the properties of the product. In other words, the question as to what type of coupon or sample will represent the product is a very important one and should, therefore, be given proper attention in our product specifications for steel as well as for other materials.

Variations in the procedure used in testing specimens may cause appreciable variations in the values obtained. In recognition of this fact, extensive testing methods have been and are being prepared by such agencies as the American Society for Testing Materials, but much remains to be done in this field. With the present trend towards more accurate testing of metals much more attention must be given to the many details of procedure that heretofore have been dependent almost entirely upon the ideas of the operator making the test. For example, considerable latitude is now permissible in the size and shape of the ends of tensile-test specimens; in the methods used in gripping tubular tensile specimens; and in the methods used for making tensile tests of steel wire. As a result of these permissible variations in testing procedure we find considerable differences in test results from different laboratories on specimens from the same lot of product. The magnitude of the variations from these sources in the test results often varies with the product. This is especially true in the case of tensile tests and hardness tests of thin sheet metals, including thin sheet steel.

Such mechanical properties as elastic limit, proportional limit, and certain modifications of the yield-point, which are usually obtained from stress-strain data are generally largely dependent on the methods used in testing. It is, therefore, essential that uniformity

in testing methods obtain if test results from various laboratories are to be satisfactorily compared.

With the more economical use of metals there is an ever increasing demand for narrower limits in the accuracy with which values of mechanical properties are determined. If variations in the mechanical properties of a product are to be determined, it is necessary that the permissible limits of accuracy required in the determination of the properties, be appreciably less than the anticipated variations in product. It is hardly sufficient to specify that the testing apparatus or machine shall give total loads within, say, one per cent., and then permit variations in methods of operation which might easily cause errors of three to five times this amount, and expect the final results to be correct within one or two per cent. Many forms of testing machines and apparatus which are called upon to impose loads of varying amounts on specimens, do not do so with the same degree of accuracy throughout their entire ranges of load. An example of this is the usual type of universal testing-machine wherein the percentage of error at the lower loads is greater than at the higher loads. Using such a machine with a given capacity range, therefore, it is appreciably more difficult to determine properties of small specimens than of larger ones which require total loads approximating the maximum value of the capacity range. Many other examples might be given all of which would merely serve to emphasize the necessity for specifying testing methods in sufficient detail to insure results of the desired accuracy. Frequently a plain statement of the tolerances desired would be very helpful.

Tests of mechanical properties are used not only in the inspection and control of a product but also as a basis of values for enginering design. In any of these uses it is well to bear in mind the statistical element involved in such data. During 1930, such men as Professor Seely at the University of Illinois*, and Dr. Shewhart of the Bell Telephone Laboratories†, have very aptly pointed out some of the things to be considered from the statistical viewpoint when using values of mechanical properties. To quote Professor Seely, "A recognition of the statistical element in the picture of material and of stress distribution is becoming of great importance in the interpre-

*_Mechanical Engineering,_ v. 52, p. 839.
†_Bell System Technical Journal,_ v. 9, p. 364.

tation of mathematical and experimental results, and in the formation of more reliable rules for design."

Dr. Shewhart has given us a workable method which, for large masses of data, permits the definite establishing of certain facts which otherwise would be obscured, largely on account of the mere mass of data available. The efforts of these men, together with similar efforts of many others, are doing much to enhance the value of mechanical tests.

Testing-Machines and Apparatus. Experience has shown that quite frequently tests of metals, including steel, are required without there being any specific purpose of the test results in mind. The big idea appears to be simply "test it." Unfortunately, there are a few examples of testing apparatus or testing-machines which so far appear to be capable of merely testing a specimen without giving results which are of generally recognized significance or usefulness. It is to be hoped that in time such tests will either die a natural death or their utility will be determined. The excuse for such machines, of course, lies mainly in a recognition of the shortcomings of some of the commonly used tests. Generally speaking, if testing-machines and apparatus are expected to remain in suitable condition they should be used for the purposes intended, and not as substitutes for other machines. The writer has seen universal testing-machines used as arbor presses, forging-presses, extrusion presses, draw-benches, etc., but the advisability of such practices is questionable, to say the least.

In selecting a testing-machine, the prospective purchaser is frequently confronted with choosing from two or more types of design. For example, universal testing-machines may be obtained in the gear-screw-power, lever-scale type; the hydraulic-power, hydraulic-lever-pendulum type; or the hydraulic-power, pressure-capsule, Bourdon-gage type. In addition, many variations in the details of each of these types are available. Each type of machine has distinct merits, but the advantages of a given type are not in agreement throughout with those of the other types.

The factors generally considered by a prospective purchaser, when enumerating the merits of a testing-machine, include cost, floor space, time of delivery, maximum load capacity, maximum specimen capacity, capacity ranges, and auxiliary attachments. It is assumed

that any of the types will be free from temperature effects; that they will give load readings within suitable limits of accuracy; that the personal equation of the operator is the same in all cases, or is negligible; that any of the specimen grips or supports are satisfactory; that good results can be obtained irrespective of the sizes of specimens to be tested as long as they come within the capacity of the machine; and that any autographic or automatic load-balancing device will answer. Unfortunately, experience has shown very definitely, that if the more precise results now being demanded in testing metals are expected, we should give major consideration to the factors previously taken for granted or not emphasized, putting such items as cost, delivery, etc., among the secondary factors. This should not be construed as an argument for or against any given type, but as a suggested change in procedure to be followed in selecting more suitable testing apparatus.

Such details of testing-machines as grips, specimen supports, load ranges, sensitivity at various loads, facilities for varying and controlling the rate of testing, and magnitude of personal equation of the machine operator, are all of importance not only in obtaining more precise test values but also in obtaining results at lower cost.

One of the mistakes most frequently made with regard to testing apparatus is the assumption that any one can operate a testing-machine and therefore can obtain satisfactory test results. Accordingly we find many cases where mechanical properties of metals are determined by persons with little if any knowledge of the mechanics of materials. The technical literature is replete with records obtained under such conditions as to preclude a satisfactory comparison of values throughout, largely because of failure on the part of the authors to appreciate the significance of the many factors involved in the determination of the data. Many of the discrepancies in test results occurring to-day between different departments of large industrial firms, and between producer and consumer, are directly attributable to differences not only in testing apparatus and nominal methods but also to differences resulting from the character of machine operators.

In applying the foregoing to the mechanical testing of various kinds of steel products we should be guided first by the rules defined in the specifications pertaining particularly to the given product, or

the general rules given by standards pertaining to the given kind of test, or both. In the interest of better results there is more that can be done which may not be fully realized by those responsible for making the tests, or which is inadequately defined in the specifications for the product.

DISCUSSION

W. B. SKINKLE, *Chairman*:* Mr. Whetzel, Chairman of the Pittsburgh Section of the American Chemical Society, is with us and we would like to have him take charge of the meeting.

J. C. WHETZEL, *Chairman*:† I am sure I express the pleasure of the chemists in joining with the engineers in this program. The next in order might be a discussion of the paper. There must be a number here who would at least like to ask some questions.

W. B. SKINKLE: Being a mechanical engineer and having spent many years designing special heavy machinery, Mr. Templin's paper has made a very strong appeal to me. His definitions of yield-point, elastic limit, and proportional limit are clear and sharp and it is too bad that a clear understanding of these terms and their value is not more general.

I have often noticed advertisements of special alloy steels, giving the ultimate strength and yield-point for the particular steel advertised, but carefully avoiding any reference to the elastic limit or proportional limit. This is probably a "hang over" from the old days of plain carbon steel when a close approximate value for the true elastic limit could be obtained by deducting 1000 or 2000 pounds per square inch from the stress at the yield-point as determined by the drop of the beam. This, however, is not true when dealing with heat-treated alloy steels, and if such practice is followed it would lead to dangerous results. Very often the yield-point of a heat-treated steel as determined by the drop of the beam is very close to the ultimate strength, whereas the elastic limit or proportional limit is considerably below the value obtained for the yield-point. As an example of this I have found the following typical examples:

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In a heat-treated low-carbon manganese steel of 0.14 per cent. carbon and 2.82 per cent. manganese, the proportional limit was 137,300 pounds per square inch, the yield-point 157,000 pounds per square inch, and the ultimate 159,400 pounds per square inch.

In a piece of chrome-nickel steel (S.A.E. 3130) the proportional limit was 73,000 pounds per square inch, the yield-point 143,000 pounds per square inch, and the ultimate 150,200 pounds per square inch.

It can be seen that the old plain carbon steel relation between yield-point and proportional limit does not hold at all when dealing with steels of this type.

A designer must keep his maximum shock stresses below the proportional limit if he is to avoid ultimate failure of the part he is designing. If he has no information on the value of this proportional limit he is forced to keep the maximum fiber stresses low or else take a long chance on failure.

In reports by so-called research men, I have seen the terms elastic limit, proportional limit, and yield-point hopelessly jumbled and mixed. Such a state of affairs seems to be worthy of considerable study.

R. L. Templin: Any detailed discussion of the elastic limit and the proportional limit is liable to be a long one. These properties are so much a function of the condition of the test specimen and the type and condition of the testing apparatus used that I am frankly skeptical of most of the data published. Even in tests of mild steel, if the specimen is slightly bent, one can obtain some very peculiar stress-strain curves. In the case of some of the heat-treated alloy steels, much trouble will be experienced in determining these properties unless the test specimens are ground all over after heat treatment. Even then, varying amounts of internal strain in the specimens due to heat treatment may cause appreciable variations in the values for the elastic or proportional limits. In addition, there are a number of other factors which may cause marked differences in the proportional limit values, which may be, and often are, more a function of the testing procedure than of the material being tested.

I am of the opinion that some method should be evolved which will eliminate as many as possible of these factors, both in defining

and determining the properties we normally call "elastic limit" or "proportional limit." This idea is not original by any means. We already have a similar proposal in Johnson's apparent elastic limit scheme and a few others similar to it. Most of these arbitrary schemes are more or less sensitive to the factors just suggested, and it would seem that the most desirable scheme is the one in which the effects of such factors are reduced to a minimum, if not quite eliminated. With such a scheme in general use, I think we can get much better agreement both in definition and determination of the mechanical property that is analogous to what we have been calling the elastic limit.

H. W. GRAHAM:* In the slides which Mr. Templin showed, he referred to one curve as representing tensile strength from the standpoint of the physicist—that is, a stress-strain curve which takes into account the fact that above the yield-point the test-piece is "necking" (decreasing in diameter), and therefore with a constantly changing relationship of beam load to cross-sectional area, as expressed in pounds per square inch. From this standpoint, the ultimate strength is perhaps 200,000 pounds per square inch, rather than 60,000 to 70,000, as is the common figure for soft structural steel when by conventional methods the ultimate load is divided by the original area of the specimen. Can Mr. Templin tell us anything of the technique used in determining that curve?

R. L. TEMPLIN: I have not actually made all of the measurements referred to. The curves shown were taken from "Materials of Construction; Their Manufacture and Properties," by A. P. Mills (John Wiley & Sons, New York). When measurements of this type are made they usually require a very precise extensometer so that very small changes in the diameter of the specimen can be determined. We have made such measurements on concrete cylinders, using a rather sensitive device for measuring change in diameter. We have also used a similar scheme in tension and compression tests of rubber. We think the same idea can be used on steel, except that it will be necessary to change the order of accuracy and sensitivity of the apparatus. The apparatus that we have used on concrete and

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rubber consists essentially of a band held tightly around the specimen with coinciding scratches on overlapping ends of the band. The displacement of these scratches as the specimen increases in diameter is measured by a compound microscope reading to 0.002 millimeter. On account of the low modulus of elasticity of the materials and the size of specimens used, this apparatus proved quite satisfactory. In the case of the concrete, the specimens were 30 inches in diameter, whereas in the case of the rubber, the specimens varied from ½ inch to 2¼ inches in diameter.

I think Professor Goodale could tell us something about Brinell hardness of sheet metal. He has had a lot of experience with that.

S. L. Goodale:* I have been very much interested in the discussion. The thickness of the sheet to be tested, also taking into consideration its hardness, determined the choice of size of the ball and weight to be used; that is, the effect of the test must be "entirely taken up within the small thickness of metal actually under test." In a general way, we found that results with the baby Brinell compare well with results when using the large Brinell machine, though they are not identical. The differences are usually not much, if any, greater than the differences between results with two different standard machines.

We experimented with a number of different sizes of ball and different weights with each size of ball, finally adopting the 1/16-inch ball and 15-kilogram weight because they gave us the best results for the work on which we were engaged. The reading of the impression diameters for the small Brinell machine is a very tedious matter if many impressions have to be read. We used a filar micrometer eyepiece, with 16-millimeter objective and a tube length chosen to give a direct reading ratio for the scale of the micrometer. Impressions can be read to 0.001 or 0.002 millimeter, and require about this accuracy for good results.

R. L. Templin: In connection with the new Vickers hardness testing machine, I would refer you to a recent number of *Engineering* (Sept. 12, 1930, page 324), wherein G. A. Hankins, of the National Physical Laboratory, reports:

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"For steel-ball Brinell tests, it is usually considered that, when the thickness of the test piece is greater than seven times the depth of the impression, satisfactory test results are obtained (see B.E.S.A. Report No. 240, 1926). In the case of the 136 deg. diamond pyramid (the indenting tool used in the well-known Vickers hardness testing machine) the application of this rule suggests that the minimum thickness of the test material should be equal to the diagonal of the test impression, but experience shows that a greater thickness may be necessary."

We use the baby Brinell hardness tester, but in order to make the results obtained from it agree with those obtained with the larger similar machine we have made a slight departure in the load on the ball from that originally used by Professor Goodale. He used a load of 15 kilograms on a ball 1/16 inch in diameter, whereas we use 12.61 kilograms. With such a combination, our Brinell hardness results compare with those obtained on the thicker material using a 500-kilogram load on a ball 10 millimeters in diameter. The use of the baby Brinell hardness machine allows us to obtain satisfactory results on sheet material in the neighborhood of 0.008 to 0.010 inch thick, depending on the grade and temper of the sheet.

C. S. PALMER:* Personally I do not know enough about this subject to ask any questions, but I am interested. I once heard Professor Henry Roland, of Johns Hopkins University, say that we talk about solids, but really we do not know that there is any such thing as a solid. Because with pressure enough and time enough everything we call a solid acts like a liquid. Does the time element enter at all into this amount of stretch or bending, or does it happen instantaneously?

R. L. TEMPLIN: That is a very pertinent question. In the determination of the so-called elastic limit, time does not have much effect, but beyond that point time does have a decided effect on the results obtained. For stresses in excess of the elastic limit, we are concerned with the plastic flow of the material, which involves a phase of the mechanics of materials about which too little is known. It involves questions which are being considered by a committee of the American Society of Mechanical Engineers, and we certainly hope that this committee will be able to give us more information on

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the subject than appears to be available to-day. The shape of the stress-strain curve beyond the elastic limit and yield-point is markedly affected by the time involved in making the stress-strain determinations.

J. O. Cook:* We had a question on the failure of iron wire in connection with time effect. The loads causing these failures would necessarily have to be considerably above the ordinary working stresses.

R. L. Templin: The tests of wire to which I referred were a form of creep test carried out at room temperatures. Such tests are not usually carried out in the ordinary type of testing-machine, and they frequently give results which are appreciably below the values that would be obtained under ordinary test conditions. In the case reported by Thurston, the ultimate strength of the material was much less than the normal test values, because the time of application of the load was many times greater than the usual amount of time involved. It may be interesting to some of you to know that we have similar tests of heat-treated "duralumin" now going on in our laboratories. These tests were started about five years ago. Dead loads up to 89 per cent. of the normal breaking strength are imposed on the material, with the result that the material flows under load. In this case the amount of flow is less than would be expected in steel or iron.

Our creep test values plotted against time give a hyperbolic curve, the rate decreasing as time goes on. The creep at the present time is so slow, however, that we can not measure it with any degree of accuracy.

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BOILER-WATER CONDITIONING; A PITTSBURGH DEVELOPMENT*

By J. N. Welsh† and H. A. Jackson‡

BOILER-WATER CONDITIONING AN EXACT ART

It seems but yesterday that the Stanwix boiler of the Allegheny County Steam Heating Company, a mammoth for the day, and embodying the new conceptions of water walls and screens, was the cynosure of all eyes. For a fleeting moment only, however. At Milwaukee, John Anderson[1§] began demonstrating the economies of operating at the then high pressure of 1200 pounds. At Kips Bay, with practically 100 per cent. untreated make-up and operating pressure of 275 pounds, Mumford[2] was meeting and solving the problems of ratings ranging from 600 to 1000 per cent., while Hofmann of the National Electric Products Company was demonstrating the possibility of operating at 425 pounds pressure while using 100 per cent. make-up of Ohio valley well water. To-day, Wheeler, with the New York Edison Company, easily getting hourly 1,250,000 pounds of steam at 400 pounds pressure from one boiler, says this is only a start. At Baton Rouge, Louisiana Steam Products contracts to deliver 750,000 pounds of steam per hour at 670 pounds pressure with 100 per cent. make-up; and in the immediate offing is the 1200-pound boiler with 100 per cent. make-up. Verily a new era in steam generation!

In the same breath, a new era in the conditioning of boiler water; an era in which the critical demands of the high ratings characterizing Kips Bay station, with their necessarily small volume of rapidly changing boiler water are readily and completely met; in which the high pressures of Milwaukee present no obstacle to clean and corrosion-free surfaces; in which to satisfy the most exacting requirements of the water walls and screens of a New York Edison mammoth is simple routine for an earnest operator.

The foundation of this success consists of timely and correct appraisal of the ever changing boiler water. Adjustments made to-day on the basis of the sample of yesterday or earlier, or on the basis of a composite sample for a preceding week, are in vain. Symbolic

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§See references at end of paper.

of the new era is the operator who has been carefully instructed by his advisers on the characteristics of boiler waters, and tests for recognizing them, and who, testing a sample immediately it is drawn, at once makes any necessary adjustments to assure correct conditions in the boiler water. There is no guesswork in what he does; for boiler-water conditioning is to-day an exact art, comprehending all pressures, all ratings; in fine, all contacts of water and metal in the steam-generating plant.

MEN AND PLANTS

The principles of boiler-water conditioning that had their inception in the co-operative investigation[3] in Pittsburgh by the Hagan Corporation and the United States Bureau of Mines, are to-day directing the trend of water conditioning the world over. The plants of the Pittsburgh district, however, have been the proving-ground on which the water-conditioning theories of the laboratory have evolved into the simple routine of operating control.

We owe much to Fischer of the Mesta Machine Company[4] and Dudley of the Jones and Laughlin Steel Corporation[5] for bearing with us in our early wrestlings with the foibles and weaknesses of soda-ash; and later, when our path led to higher pressures, the interest and co-operation of Hankison of the West Penn Power Company[6] resulted in establishing as a fact, that maintenance of the desired equilibria at the evaporative surfaces with phosphate eradicated scale deposition at high as well as low pressures. Bleyer of the National Tube Company, at Lorain, Ohio; Mumford of the New York Steam Corporation; and later, Rath of the National Tube Company, McKeesport, Pa., and Hofmann of the National Electric Products Company at Ambridge, Pa., by their co-operation, have contributed their share to the present definiteness of the art of water conditioning. Progress often has its inception in friendly discussion sometimes with agreement, sometimes with disagreement; and in this way Hecht of the Duquesne Light Company, who is contributing largely to the solution of many chemical problems in the central-station industry, and Call of the Beech Bottom station, have been a stimulus to us in our work.

Thus we need not go far afield for plants illustrative of application of the principles of boiler-water conditioning, and shall use in this discussion only those in or near Pittsburgh.

FUNDAMENTAL PRINCIPLES OF BOILER-WATER CONDITIONING

The water conditioning requirements of a boiler water vary with variation of the dissolved components therein and with different operating pressures. The fundamental requirements are briefly as follows:[7]

1. The boiler water must contain in dissolved form a chosen material (carbonate or phosphate) in amount sufficient to assure constant maintenance of desired chemical equilibria at the evaporative surfaces. Simple routine tests are guide-posts to desirable maintenance. Choice between carbonate and phosphate is based on operating pressure, since rapid decomposition of carbonate at higher pressures renders its use both ineffectual and uneconomic.
2. The alkalinity of the boiler water must be maintained within low, well defined limits at all times.
3. The boiler water must be kept free of saponifiable matter and organic contamination.
4. Every effort must be made to obtain the minimum concentration of dissolved solids in the feed-water so that necessary limitation thereof in the boiler water shall not be purchased at the expense of excessive blow down.
5. It is more important that the collective total of dissolved and suspended solids in the boiler water be a minimum, than to accept increased concentration of the total for the sake of decreasing the latter a few parts per million.

Condition No. 1 is the main theorem of boiler-water conditioning. We may illustrate its meaning thus:

The chemical maintained in the boiler water is the actively engaged front line of defense against scale; the routine test on the boiler water is the roll-call to determine the number of casualties since the preceding test; and any change in rate of addition of chemical is merely the pro-rating of reinforcements to maintain the front line at full fighting strength. It was the opportunity of the co-operative research to define the necessary strength and character of the front line of defense for all possible operating conditions; efficient

maintenance—the responsibility of the operator and none other—presents an impregnable defense that holds inviolate the cleanliness of surfaces.

Each of the other conditions has its specific significance, and they are subsidiary to condition No. 1. Paragraph No. 2 relates to prevention of corrosion and proper functioning of the phosphate chemical. Up and down these high-sulphate rivers of the Pittsburgh district, the item of low, well defined limits of boiler-water alkalinity has many times suffered severely in the vain effort to maintain cleanliness of surfaces by use of ever increasing quantities of the ineffectual carbonate. In so doing, the tenets of conditions 4 and 5, relating to carry over of the boiler water in the steam, have not been visualized, and not infrequently from a third to a half of the total dissolved solids in the boiler water have had their origin in the added treating chemical. The item of low alkalinity renders simple the maintenance of all boiler-water ratios recommended to prevent the cracking of boiler metal.

Condition 3 merely states that it is better to remove harmful contamination (oil, grease, sewage, and organic saponifiable material) from feed-water rather than attempt correction thereof in the boiler water.[8]

VARIOUS CASES ILLUSTRATIVE OF BOILER-WATER CONDITIONING

Case 1. This was a case of direct conditioning by soda-ash. This plant is situated in Homestead. It has 545-horse-power, longitudinal-drum, Heine boilers. The operating pressure is 150 pounds, and the rating is 175 per cent. average, with sudden changes to 275 per cent. Make-up is 100 per cent. of South Pittsburgh (Monongahela River) water. Soda-ash as conditioning material is added directly to the boiler water by means of a small chemical pump, thus avoiding trouble of feed-line deposition that would occur were it added at the heater or to the suction side of the boiler feed pump.

It was here in 1922 that our first plant experimental work was done, in co-operation with Carl Fischer, superintendent of light, heat and power. We will not burden you with details of this work, as they are available in technical papers.[4] The most striking feature encountered was that the boiler water resulting from evaporation of

the city water, and producing large quantities of beautifully pure calcium sulphate scale, was, without filtration, clear enough for drinking water. In this boiler water there was no case of precipitation of small individual particles which by incidental lodgement on the evaporative surfaces were congealed into hard scale. This was true crystallization from a supersaturated solution directly on the surfaces, and so prevention of boiler-scale formation resolved itself into recognition of desirable equilibria at the evaporative surfaces and their efficient maintenance. Decision to this effect immediately destroyed all credence in any of the fantastic and nebulous colloid methods of scale prevention, whether the colloid was said to be a rare product of sea or of land.

The question of how much soda-ash was necessary to maintain the desired equilibria was answered later, in 1923, and Mr. Fischer was the recipient of the first set of curves ever drawn in the whole history of water treating showing the necessary ratio of carbonate to sulphate in his boiler waters for his operating pressure of 150 pounds. Those same curves control his water conditioning to-day. Whereas, previous to their use, each boiler required turbining every two months (cleaning requiring three days), with their use turbining occurs once or twice a year, requiring one day. Three boilers with clean surfaces readily carry the load which four had carried previously, and worth-while savings in fuel have been effected.

Case 2. This case relates to direct conditioning by phosphate. The curves we had developed led us to the conclusion that successful results from conditioning by soda-ash were unattainable at operating pressures in excess of 210 pounds, and to-day we believe that soda-ash should not be used as a final conditioning chemical much above 150 pounds.

That maintenance of phosphate in the boiler water in place of attempted maintenance of carbonate was a solution to the problems of scale formation at higher operating pressure, was demonstrated for the first time at the Springdale plant of the West Penn Power Company.[9] These boilers, with an operating pressure of 325-350 pounds (now to be raised to 375 pounds), ratings of 275-550 per cent. and raw-water make-up of about 0.25 per cent., developed considerable calcium sulphate scale in spite of careful treatment with

soda-ash. In April of 1924, Hankison, with Sprague controlling conditions on the boilers, began the maintenance of phosphate in the boiler water. From that date to the present there has been no burning out of tubes due to scale formation, and there has been no turbining of boilers since January, 1925, although prior to maintenance of phosphate, the boilers were turbined annually or semi-annually, and even then considerable loss of tubes was experienced.

Tribute should be paid to Hankison, Sheppard, and the West Penn Power Company organization, for their monumental work regarding moisture in steam. In its early days there were those who held phosphate treatment as most specifically contributory to wet steam, not realizing as yet that the low boiler-water alkalinity required for satisfactory phosphate conditioning, actually made this type of conditioning much less productive of wet steam. Hankison was confronted by the dilemma of deposits in superheaters from carry over, but desired to continue phosphate conditioning because of the merits he had found therein. The results of his extensive investigation, extending over many months, may be summarized in the statement that the phosphate treatment has continued uninterruptedly, and that elimination of trouble from wet steam followed more careful adjustment of water-levels, boiler-water alkalinities, boiler-water concentrations, and elimination of organic contamination.

Thus, by the experience with the Mesta Machine Company and the West Penn Power Company, the different fields in which soda-ash or phosphate was capable of producing and maintaining clean evaporative surfaces, had been defined.

Case 3. Our next example is that of a pumping station in the Oakland district (Pittsburgh) having two gas-fired Babcock & Wilcox longitudinal-drum boilers of 450 and 340 horse-power, respectively, operating at 155 pounds gage pressure, 75 per cent. of rating, with make-up of approximately 95 per cent. Pittsburgh city (Allegheny River) water.

This is a case in which soda-ash conditioning should be effective. However, after 61 days of continuous service with soda-ash conditioning, a boiler was taken off the line and heavy scale was found in those sections of tubes, in the first pass of the boiler. Eleven tubes had to be replaced even though operating instructions for using soda-

ash had been carefully followed. Investigation showed that the gas firing resulted in extremely high temperatures in the first pass of the boiler. The temperatures of boiler water developed at this location in the boiler must have exceeded the maximum at which soda-ash is efficaceous, for scale resulted.

Conditioning was immediately begun with trisodium phosphate but less than one month later trouble with scale and burned-out tubes was again experienced. The scale which caused the trouble was of no great thickness but broken pieces had collected in the section of the tubes corresponding to the first pass of the boiler. It was the effect of these masses of scale which caused the failure of tubes. Analysis of the scale showed it to consist mainly of calcium sulphate; thus, in this case, even with phosphate treatment, calcium sulphate scale formed in a boiler operating at 155 pounds pressure although at the plant of the West Penn Power Company, phosphate was maintaining clean boilers at 350 pounds pressure. A comparison of the records of the two plants, however, shows that at the plant of the West Penn Power Company available phosphate was maintained in the boiler water, while at the pumping-station plant the records just as positively indicate that there was no available phosphate in the boiler water. Herein lies the difference between casual inexact boiler-water treatment and the exact boiler-water conditioning that maintains scale-free evaporative surfaces, whatever conditions are imposed. The quantity of phosphate added was increased accordingly and tests showed available phosphate to be present in the boiler water. Nevertheless, in a short time scale and blistering of tubes again occurred. On tracing this down, it was found that the city water had slipped over to the acid side and that the boiler-water alkalinity had disappeared. Although in technical papers we had carefully written about the necessity of maintenance of hydroxid alkalinity in the boiler water, when it came to actual practice we had overlooked this point. The boiler was put back on the line, enough alkaline chemical introduced with the phosphate to provide the necessary caustic alkalinity in the boiler water whereupon the amount of phosphate required decreased one-third and, from then on, successful results followed the phosphate conditioning.

Case 4. Our next example takes us slightly out of the Pittsburgh district to the steel manufacturing industry of northern Ohio. Since 1924 the water conditioning at this plant has been growing up simultaneously with the developments of the co-operative research and the research fostered under the auspices of Hall Laboratories, Inc., following discontinuance in 1926 of the investigation at the United States Bureau of Mines.

At the time of beginning work at this plant, the feed-water for six 1950-horse-power Bigelow-Hornsby boilers operating at 160 pounds pressure, was taken from a small, variable, high-sulphate river, and softened in a batch-process lime-soda system operating at about 100 degrees F. Despite fairly efficient softening of the water, the steam-generating tubes nearest the furnace in these boilers, quickly became covered with scale, requiring frequent turbining and resulting in severe loss of tubes.[10] As it was proposed eventually to operate these boilers at 275 pounds pressure, it was evident that a radical change must be made to make this elevation in pressure economical and successful.

At the operating pressure of 160 pounds, two methods of attack were available:

1. To introduce soda-ash directly into the evaporative element of the Bigelow-Hornsby boiler, making up for the deficiency caused by decomposition of the soda-ash in the economizer and pre-heating sections.
2. To accept the added cost of phosphate and use this stable radical for the final conditioning of the entire boiler.

The latter course was chosen and has been followed continuously from that date to the present. The operating pressures have been increased to 265 pounds, the same softener is functioning to-day as then, and despite variability and high sulphate of the river water, cleanliness of surfaces has been continuous except that for a short period, when attempting to maintain extremely low alkalinities in the boiler water, some silicate deposits were formed. This is another factor in control of phosphate conditioning—that in high-silicate waters a higher alkalinity must be maintained for cleanliness of surfaces than in a water not thus contaminated.

To-day, three additional boilers of large capacity have been added to the original six, and the load of the plant is being gradually shifted to this central power station.

Another phase of water conditioning at this plant is of interest. Originally the boiler waters were a deep wine red. Extraction of the saponifiable matter therein showed the presence of large quantities of oil. Investigation determined the fact that the raw water, while apparently of extremely polluted character, was not causative of this condition, but that the contamination must arise from the plant returns. Although this seemed impossible to the operators, they gave to elimination of this condition the splendid co-operation that has always marked our co-operative work, and which after all is the determining factor between splendid and indifferent results. During two years, every possible return of oil from the plant was hunted out and dried up, or else the contaminated steam was turned to the sewer. As a result of this diligent search, the boiler waters to-day with practically 100 per cent. make-up from this small dirty river, are almost water white. The significance of lack of color is evidence of absence of contaminating organic saponifiable material, and the result from elimination thereof is reflected in the tremendously better boiling conditions and better quality of steam produced to-day.

A third factor of interest at this plant is that, due to insufficient de-aëration, the feed-water, although alkaline, produced corrosion in the economizer sections. While the de-aëration and alkalinity have been sufficient to protect high-velocity economizers from corrosion, the problem of corrosion in the low-velocity economizers was serious. Mechanically applied protective coatings most carefully applied to the economizers proved of insufficient benefit in stopping corrosion to be economic of application. To-day this problem is being taken care of by installation of sufficient de-aërating capacity.

Over a period of six years at this plant the work has gone on and step by step the various problems presented by the steam-generating plant have been met until to-day the boiler-water conditioning is as exact a proposition as any other operation in the steam plant.

We will comment upon just one more feature of the work at this plant. During the years 1926-1928 in our laboratory we carried out a large amount of research on use of anti-foam materials.[11]

Materials that possess anti-foam characteristics for a fully treated water are all organic in character. Like all organic bodies, therefore, their stability decreases with increasing temperature and at the temperature of boiler waters their degeneration and saponification in the alkaline boiler water renders of brief duration any effectiveness they may originally possess in this direction. These results of laboratory work were checked by plant experiment on boilers at 150 pounds pressure, and fortunately were never attempted even experimentally at the plant in question. We believe the right course, not only for this plant but for all plants, was chosen—to prevent the entrance of contamination to the boiler water rather than to load the boiler water with concoctions in the effort to nullify pernicious effects.

Case 5. Our next example takes us to a steel plant in the Pittsburgh district using Monongahela River water contaminated by the Youghiogheny River. The point of importance in this case is the fact that the lime-soda batch process operating at approximately 100 degrees F., supplies water to certain boilers operating at 150 pounds pressure, and to certain others operating at 250 pounds pressure. The simplicity of maintaining clean surfaces throughout the plant as well as conditions of desirable alkalinities in the boiler water by methods of boiler-water conditioning is well illustrated by this case.

The softener is run to give a moderately complete separation of the scale-forming components in the water, but excessive amounts of soda-ash and lime are avoided. However, in those plants running at 150 pounds pressure, auxiliary soda-ash is added at the heater in conformity with the demands registered by tests on the boiler water, for maintaining the necessary carbonate-sulphate ratios therein.

At the plant operating at 250 pounds pressure, auxiliary alkali-reducing phosphate is introduced at the heater, placing the final conditioning of the boiler water on the phosphate basis; and (because an alkali-reducing phosphate is used for this purpose) maintaining in the boiler water alkalinities that are pleasingly low.

The introduction of phosphate at the heater in this manner has created for the laboratories a problem of consequence because of development of phosphate deposits in feed lines. Temporary relief[12] was obtained by adding with the phosphate, the necessary quantities of a

tannic acid body as quebracho extract, in order to stay precipitation of the calcium phosphate for a brief period and thus eliminate feed-line deposits. Of various possible organic bodies, the tannic acid material was chosen because it offers the least possibility of degeneration into saponifiable materials in the boiler water.

Within recent months the Laboratories have developed a molecularly dehydrated phosphate that gives freedom at this plant from all feed-line deposits without addition of any organic material whatever. This development of the Laboratories has the further notable property that while being nearly neutral as present in the feed-water it becomes strongly alkali-reducing in the boiler water and hence gives an excellent control over boiler-water alkalinities.

Thus the difficulties inherent in operating boilers of different pressures from the same softener are overcome by boiler-water conditioning. It has been simpler to obtain desired cleanliness of surfaces in the 250-pound boilers with phosphate than in the 150-pound boilers using carbonate. Thus cleaning has not been necessary on these 250-pound boilers since the last one was turbined on October 12, 1927, and on inspection this spring they have been found perfectly free from scale and corrosion.

Case 6. In this plant feed-water for boilers of 125 pounds pressure is softened by "zeolite" using McKeesport city (Monongahela River) water. Some scale and too low alkalinity in the boiler water have been the problem. It has been rectified by the addition of soda-ash to the feed-water in amounts sufficient to maintain the correct carbonate-sulphate relations in the boiler water.

Case 7. In this plant, the boilers at operating pressures of 100 to 150 pounds derive their feed-water from well water treated with "zeolite". When the "zeolite" is new the boiler waters develop too high alkalinity. Addition of coagulant and filtration of the raw water are unable to remove the mineral oil completely, and the efficiency of the "zeolite" rapidly decreases.

The flexibility of boiler-water conditioning and boiler-water control obviates difficulties for this plant. When the mineral is fresh and the alkalinities too high, sufficient raw well water is by-passed directly to the boiler to reduce the alkalinities to the point where the

desirable carbonate-sulphate ratios obtain in the boiler water. As the activity of "zeolite" decreases, addition of sodium carbonate becomes necessary and is made in amount sufficient to maintain the carbonate-sulphate ratios. Simple routine tests on the boiler water tell the story of what is necessary and thus protect the boiler surfaces although feed-water conditions are subject to wide variation.

Case 8. Three or four years ago we all observed with disquietude the plans going forward at Ambridge for the operation of a boiler at 425 pounds with 100 per cent. make-up of Ohio valley well water. The well waters of this district are, in general, of considerably higher content of dissolved solids than are the river waters, with the exception of Youghiogheny River water.

The boiler was erected and placed in operation. Available for treatment of the water was a continuous hot-process lime-soda softener without filters, which had served its purpose quite well in preparing feed-water for the 125-pound Wickes boilers which were predecessors of the new high-pressure boiler.

One can not expect lime-soda treated water to maintain clean surfaces with high percentage make-up at this operating pressure. The fault lies not in the softener but in the fact that soda-ash does not have permanent qualities at high temperatures, and its decomposition in the boiler water renders its presence unavailing to inhibit scale formation. One wonders at the temerity of a boiler-compound man who, probably ignorant of the quality of the Ohio valley well water, recommended discontinuance of a softener on this water in favor of his special concoction. When we were asked to co-operate in this problem of water conditioning, we were only too glad to avail ourselves of every bit of help that could be derived from the softener prior to the control of the boiler-water conditions by the phosphate chemical.

Our first step was to make certain that the proportioner of the softener should work efficiently, and that we should therefore derive from the softener in the absence of filters as clear a water as possible. With that done, and with the complete co-operation of the operator, the results are as follows. Continuous maintenance of phosphate in the boiler water has resulted in a cleanliness of surfaces and in absence of tube loss that was perfect from the period of start over two years

ago until very recently when in the attempt to bring the alkalinities of the boiler water exceedingly low we overstepped the safe limit and lost a few tubes. This, however, is but an incident and with our safe lower limit of alkalinity established there will be no recurrence. The only turbining these boilers have had has been an annual passage of the turbines through the tubes to knock off the external accumulations thereon.

Case. 9. In our final example, where a recent installation of boilers at 400 pounds pressure, operating with 100 per cent. make-up of Monongahela River water, must be maintained in continuous operation, a combination of the most recent type of hot-process continuous lime-soda softener with phosphate conditioning by the newly developed molecularly dehydrated phosphate, has proved very successful. Due to the characteristics of the boilers, large blow down is necessary; but, despite this, operation of the softener on the low-excess alkalinities that are required at the temperature of the hot-process equipment in conjunction with the alkali reduction effected by the phosphate, have served to give the low alkalinities in the boiler water that permit maximum concentration of dissolved solids therein without causing moisture in the steam.

The water conditioning at this plant, carefully laid out in advance, has gone into operation practically as planned, with the exception that the molecularly dehydrated phosphate has been substituted for the disodium phosphate recommended in the beginning, to relieve the possibilities of trouble from feed-line scale. We are glad to state that during the period of initiation of operation when difficulties seem to pile one on another, at least the difficulty of scale deposition on the tubes has been obviated, and no shut-down because of burned-out tubes has occurred.

CONCLUSION

In conclusion we can do no better than to reiterate a statement previously made—boiler-water conditioning is to-day an exact art comprehending all pressures, all ratings; in fine, all contacts of water and metal in the steam-generating plant. Boiler-water conditioning is a Pittsburgh development, and we are indebted to many plants of the Pittsburgh district for their co-operation and helpfulness therewith.

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3. **Hall**, R. E. *and others.*
   Physico-chemical study of scale formation and boiler-water conditioning. 239 p. 1927. Carnegie Institute of Technology, Pittsburgh. (Mining and Metallurgical Investigations. Bulletin 24.)

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5. **Hall**, R. E.
   System of boiler water treatment based on chemical equilibrium. 1925. (Industrial and Engineering Chemistry, v. 17, p. 283–290.)

6. Statement by the West Penn Power Company. 1925. (National Electric Light Association Proceedings, v. 82, p. 1313–1315.)
   Part of general report on treatment of feed-water.

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   Boiler operation at high pressure demands exact water conditioning. 1929. (Power, v. 69, p. 873–875.)

8. **Hall**, R. E.
   Some examples and precepts of water conditioning. 1929. (Industrial and Engineering Chemistry, v. 21, p. 824–829.)

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10. **Hall**, R. E.
    Fundamentals in the conditioning of boiler waters. 1925. (Proceedings of the Engineers' Society of Western Pennsylvania, v. 41, p. 347–390.)

11. Statement by the Hall Laboratories, Inc., Pittsburgh. 1928. (National Electric Light Association Proceedings, v. 85, p. 1392-1395.)

12. **Hagan Corporation.**
    Scientific research solves the boiler-water conditioning problem. Pittsburgh.

DISCUSSION

EDWARD A. BROWN, JR.:* After hearing this excellent paper, I want merely to raise the question as to whether the speaker considers the treatment a limitation to the rating possible to carry, or if he would care to place the limit of rating possible, say, for bent-tube or horizontal-tube boilers with water as he proposes to have it treated.

Personally, I have always believed that with our heavily loaded waters which it is necessary to use for boiler purposes in most of our plants, even with the best treatment, it was far inferior to condensate and did limit the possible rating. I would be pleased to have the speaker discuss this phase of his subject if he would care to do so.

O. P. ADAMS:† The Society might be interested in the method employed at our boiler houses to equalize the rate of feed to the various drums of longitudinal-drum water-tube boilers.

Orifice plates proportioned for a five-pound drop in pressure at slightly above the average rate of feed were inserted in the individual feed lines near the drums. This five-pound drop is vastly greater in proportion than any other factor affecting the rate of flow of water into the drum, as the friction loss through fittings and pipe and the variation in level of water in the drums are comparatively small in magnitude. The net result is that the total frictional resistance opposing the flow of the water from the outlet of the regulating valve to the drum is within a few per cent. of the same amount for each drum, regardless of the piping lay-out or variation of water-level in the drums, and, as a consequence, the rate of feed is equalized within a few per cent.

Since installing these orifice plates we have been able to maintain fairly uniform concentrations throughout the boiler. Previous to this time, concentrations in the drums varied widely, the water in one drum occasionally showing three times the concentration found in another on the same boiler.

T. G. TIMBY:‡ In this very interesting paper, mention has been made of the fact that saponifiable organic matter is not permissible in a boiler water. I should like to ask Mr. Welsh what type or kind of organic material is permissible in boiler water.

*Assistant to Chief Mechanical Engineer, Carnegie Steel Co., Munhall, Pa.
†Superintendent of Mechanical Power, National Tube Co., McKeesport, Pa.
‡McKeesport Tin Plate Co., McKeesport, Pa.

J. N. Welsh: In our work, all organic matter is considered undesirable in boiler waters. Not because all organic matter is specifically deleterious to boiler operation, but because its introduction to boiler water in most cases entails addition of organic saponifiable material, either as such or as compounds susceptible of decomposition, at the temperatures encountered, to form saponifiable material. We might, however, consider as permissible, even though undesirable, those organic materials which are not themselves specifically deleterious to boiler operation, which, if volatilized and carried along with the steam are not harmful to post-boiler equipment, and which are fairly stable at the temperature of the boiler water.

BOARD OF DIRECTION MEETING

January 14, 1930

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor D of the William Penn Hotel, Tuesday, January 14, at 12 o'clock, President W. L. Affelder presiding, Messrs. A. S. Davison, L. C. Edgar, V. R. Covell, J. A. Hunter, C. E. Lesher, W. B. Skinkle and L. E. Young being present, Messrs. J. I. Alexander, C. A. Carpenter, J. N. Chester, J. F. Laboon, G. T. Ladd T. J. McLoughlin, B. R. Shover, G. F. Siefers and A. Stucki being absent.

The minutes of the last regular meeting, held December 17, 1929, were approved without reading.

Applications from the following gentlemen, having been published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

De Berry, Sanford E.	Morrison, B. Frank
Cadwallader, James A.	Nelms, Harvey J.
Cox, Roy Lipscomb	Tomlinson, John Edward
Garretson, Forrest D.	Turner, Harold Lewis
Gibbs, C. Willard	Unkefer, Frederick D.
Kaltenbach, Earl G.	Wagner, Anthony

ASSOCIATE

Knowlton, Arthur Reid

JUNIOR

Williams, Charles Henry

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Bingham, William Charles	Newlon, John Hawker
Judy, Edward W.	Osborne, Raymond Storms
Lytle, William Orland	Winslow, George W.

ASSOCIATE

Swem, George A.

Applications for transfer to a higher grade were received from the following, and after discussion it was moved and carried that they be transferred to higher grades: Walter John Blenko (Member), Fred Ellman (Associate Member).

The report of the Secretary, showing the condition of the finances at the close of business December 31, having been audited by the Finance Committee, was approved.

Mr. Covell, Chairman of the House Committee, reported an evening attendance of 400 for the month of December.

The Membership Committee held one meeting to go over applications received since the last meeting of the Board, and to act on any other business coming before the Committee.

In accordance with action taken at the last meeting of the Board, Mr. L. C. Edgar, Chairman of the Special Committee on the celebration of our Fiftieth Anniversary, presented his report.

After a general discussion, it was moved and carried that the President be authorized to appoint a committee of about five to have charge of this

celebration, these committeemen to act as chairmen of sub-committees to handle the details. It was further recommended that the plan, generally outlined by Mr. Edgar's committee, be followed in making arrangements.

The meeting adjourned at 1:15 P. M.

K. F. TRESCHOW, *Secretary.*

ANNUAL MEETING

January 14, 1930

The fiftieth annual meeting of the Engineers' Society of Western Pennsylvania was held in the Blue Room of the William Penn Hotel, Tuesday evning, January 14, at 8:15 o'clock, Vice President L. C. Edgar presiding in the absence of President J. N. Chester, 185 members and visitors being present.

The minutes of the last annual meeting, held January 22, 1929, were read and approved.

The annual report of the Board of Direction, including the reports of the Standing Committees, the Sections and the Treasurer, were read as follows:

REPORT OF BOARD OF DIRECTION

During the year, ten meetings of the Board of Direction were held, at which the routine business of the Society was transacted.

The Board has in the past had considerable discussion as to the various activities of our Society, especially this year, due to the condition of our finances. It is difficult, of course, in an organization as large as ours to give everyone the type of meeting in which they are particularly interested and the social activities which they most enjoy. It is only through the co-operation of the members in supporting these functions by their attendance, or in sending in suggestions for other activities, that we can hope to succeed. We, therefore, bespeak your co-operation during the coming year in taking an active part in the work of the Society and giving us the benefit of any suggestions you may have for its betterment.

Respectfully submitted,

K. F. TRESCHOW, *Secretary.*

REPORT OF ENTERTAINMENT COMMITTEE

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

DEAR SIRS:

Your Entertainment Committee desires to submit the following report of the social activities of the Society during the year:

Annual Banquet	February 4, 1929	Attendance	1025
Annual Open House	March 8, 1929	Attendance	217
Bridge Party	May 10, 1929	Attendance	140
Annual Boat Ride	June 17, 1929	Attendance	242
Golf Tournament—Pittsburgh Field Club	June 24, 1929	Attendance	83
Golf Tournament—Westmoreland Country Club	September 23, 1929	Attendance	102
Hallowe'en Party	October 29, 1929	Attendance	116
			1925

With the exception of slight decreases in the Annual Banquet and Annual Boat Ride, there was a decided increase in each activity in 1929 over 1928. Your Committee is very much encouraged over this increase and feels that the social activities materially help the development of the Society affairs.

Bridge and Chess Tournaments were held as usual.

Respectfully submitted,

Allen S. Davison, *Chairman.*

REPORT OF FINANCE COMMITTEE

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

In accordance with the established custom, an independent audit of the Society's accounts was made this year by Mr. W. B. Hanson, Certified Public Accountant.

Your Finance Committee has held several meetings during the year, at which finances of the Society were discussed, budget planned, etc.

The real problem of this Committee, during the past year, has been the discussion and final recommendation for the increase of dues, which has been voted upon and adopted. As stated in the letter to the membership, this subject has been under discussion for several years and every effort made by both the Finance Committee and the Board of Direction to balance our budgets under the present dues. However, each year it has become increasingly difficult until we were finally obliged to ask the permission of the membership to raise the dues to $20.00 per year, in order that we may maintain our present activities and continue to give the membership those activities and services essential to the continued welfare of our organization.

At the beginning of the year, receipts and expenditures were estimated by the Committee as follows:

Receipts	$24,255.00
Expenditures	23,840.00

Actual expenditures and receipts were:

Receipts	$24,369.41
Expenditures	26,284.86

It can easily be seen from the above figures that an increase in dues was absolutely essential and the Committee believes that with this gain in revenue the Society can again be placed on a sound financial basis.

Respectfully submitted,

C. E. Lesher, *Chairman.*

REPORT OF HOUSE COMMITTEE

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

In presenting the annual report of the House Committee, I wish to advise that we had an evening attendance of 3500 during the past year.

The enlargement and remodeling of the William Penn Hotel, which was completed during the past year, brought a suggestion from the hotel management that the Society consider taking rooms on the third floor of the building in place of those occupied in the lower lobby. It was also requested that if we

remained in the lower lobby, we relinquish the room used as an office, workroom and coatroom and take, in lieu of this, rooms adjoining on the Grant street side of the clubroom.

In reaching a decision consideration was given to several matters, as follows:

1. The unsatisfactory ventilation which had obtained in the old quarters, a condition which was more aggravated during the remodeling period. Assurance was given by the hotel management that this difficulty would be remedied if we remained in the lower lobby.

2. The advantage of proximity to the cafeteria which is afforded by the lower lobby location and the difficulty of working out any satisfactory method to provide lunches on the third floor.

3. The disadvantage of bringing strangers and visitors into the combined office and workroom as against the advantage of giving them their introduction to the Society through the more attractive clubroom.

4. The large added expense involved if adequate quarters were chosen on the third floor.

After a number of committee meetings and several joint sessions with the Board of Direction in special meetings, at which all of the various phases of the matter were discussed, it was decided to remain in the lower lobby, to relinquish the former office and coatroom and to accept the present arrangement of rooms with the committee room, coatroom, general office and Secretary's room adjoining the clubroom on the Grant street side, and a five-year lease was signed.

The new scheme has worked out very satisfactorily, although the hotel management is still endeavoring to improve the ventilation of the clubroom. The office furniture which had been in use approximately twenty years and was about worn out was replaced by new furniture, upon the authorization of the Board of Direction.

Respectfully submitted,

V. R. Covell, *Chairman.*

REPORT OF MEMBERSHIP COMMITTEE

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

The Membership Committee held ten meetings during the past year for the transaction of its regular business.

One hundred and one new members were elected during the year. The membership as of December 31, 1929, was 1651, divided as follows:

Honorary Members	1
Members	1303
Associate Members	183
Associates	84
Juniors	71
Student Juniors	9
	1651

Changes during the year were as follows:

Dropped	60
Resignations	87
Deaths	10
Accessions	109

It seems doubtful whether the members in general are accomplishing as much as they could in the way of assisting the Membership Committee in increasing the number of eligible members. There are undoubtedly a large number of engineers in the Pittsburgh district eligible for membership who, if they knew of their eligibility and of the advantages of the Society, would be very much pleased to become affiliated with the Society. While the membership has been growing at a fairly satisfactory rate, the number could easily be increased to or above 2000 by very little effort upon the part of the present members. I trust that the members in general will recognize the possibilities and value of their co-operation with the new Membership Committee.

Thanks are extended to the members of this Committee for their splendid assistance and co-operation.

Respectfully submitted,

W. L. Affelder, *Chairman.*

REPORT OF PUBLICATION COMMITTEE

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

The Publication Committee submits the following report of its activities for the past year:

Meetings were held at various times by this Committee to discuss and arrange programs for the various meetings of the Society during the year.

In view of the fact that various Section meetings devoted the time to technical subjects of interest to those engineers associated with the various Sections, it was thought desirable to devote the time at monthly meetings to something more general so as not to overlap the work of the Sections, and with the view of making the meetings of greater interest, for good fellowship and for enlarging on the fraternal spirit of the Society. If this is not what the Society wants, and is not of interest, of course, to maintain and operate lecture courses, we require the patronage of the Society, which we hope will be forthcoming.

We have had quite a number of fine lectures, and hope to have some unusually good speakers during the coming season, your especial attention being invited to the following lectures:

Count Felix Von Luckner............................January 23
Lowell Thomas ....February
Arthur G. Pillsbury..March

It is hoped that those who do not have season tickets will avail themselves of the opportunity and patronize these lecture courses.

Respectfully submitted,

L. C. Edgar, *Chairman.*

REPORT OF TREASURER

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

DEAR SIRS:

Your Treasurer desires to submit the following report for the year 1929:

RECEIPTS

Dues Collected	$18,712.11	
Entrance Fees	830.00	
Advertising—PROCEEDINGS	4,341.02	
Sale of PROCEEDINGS	239.75	
Sale of Reprints	301.14	
Sale of Society Pins	63.00	
Interest from Bonds	1,120.00	
Interest on Bank Balances	154.10	
Receipts from Banquet	7,119.00	
Receipts from Open House Party	542.50	
Receipts from Bridge Party	198.00	
Receipts from Boat Excursion	341.00	
Receipts from Golf Tournament	1,162.58	
Receipts from Hallowe'en Party	282.50	
All-Day Conferences—Luncheons	271.75	
Enrollment and Tickets—Lecture Course	860.00	
Refunds on Cuts for PROCEEDINGS	74.99	
Sale of Office Furniture	39.50	
Miscellaneous	6.47	
Total Receipts		$36,659.41

DISBURSEMENTS

Administrative and General	$18,958.45	
Cost of Magazine PROCEEDINGS	4,394.71	
Furniture and Fixtures	429.60	
Election Night Party, 1928	62.50	
Open House Party	897.45	
Bridge Party	271.05	
Boat Excursion	620.58	
Hallowe'en Party	621.82	
Golf Tournaments	1,530.08	
Sundry Other Entertainment	1,500.69	
Sectional Expense	2,391.88	
Annual Banquet, 1929	6,215.50	
Annual Banquet, 1930	255.55	
Total Expenditures		38,149.86
Excess of Expenditures Over Receipts		$ 1,490.45

CASH ASSETS

	December 31	
	1928	1929
Permanent Fund (Bonds)	$21,885.00	$21,200.00
General Fund—Cash (First National Bank)	1,313.70	305.40
Reserve Fund—Cash (Fidelity Title & Trust Co.)	2,500.00	....
Permanent Fund	825.51	1,743.36
Totals	$26,524.21	$23,248.76

Bond Investments

Two Connellsville Water Co. 5 per cent., 40-year Gold Bonds, Nos. 317-18, maturing October 1, 1839	$ 1,800.00
Three Follansbee Bros. Co. 1st Mtge., 5 per cent. SF Gold Bonds, Nos. 788-9-90, maturing June 1, 1947	2,880.00
Two Jamison Coal & Coke Co. 1st Mtge., 5 per cent. SF Gold Bonds, Nos. 1502-3, maturing May 1, 1931	1,960.00
Three Jones & Laughlin Steel Co. 1st Mtge., 30-year, 5 per cent. Gold Bonds, Nos. 3020-1-2, maturing May 1, 1939	3,060.00
Two Portsmouth, Berkeley & Suffolk Water Co. 40-year Gold Mtge. Bonds, 5 per cent., Nos. 465 and 466, maturing November 1, 1944	1,900.00
Two Shell Pipe Line Corp. 25-year SF Gold Debenture Bonds, 5 per cent., Nos. 9721-24129, maturing November 1, 1952	1,860.00
Four Spang, Chalfant & Co. 1st Mtge. SF Gold Bonds, 5 per cent., Nos. 4593-4-1596-1600, maturing January 1, 1948	3,740.00
Four Wheeling Steel Corp. 1st Refg. SF Mtge. Bonds, 5½ per cent., Nos. 8518-9 and 533-4, maturing July 1, 1948	4,000.00
Total	$21,200.00

REPORT OF CIVIL SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

I wish to submit a report of the work done by the Civil Section during the year 1929.

Six meetings of the Section were held, one being the annual meeting and one an all-day conference. The average attendance was 114, the maximum being at the May 7th meeting, with an attendance of 160, and the minimum at the March 5th meeting, with an attendance of 54. The average number discussing papers was 15.

January 8—Annual meeting. "Precast Concrete Piles and Special Equipment for Handling and Placing," Maxwell M. Upson, Vice President and General Manager, Raymond Concrete Pile Co., New York, N. Y. "The Importance of River Terminals and Docking Facilities in the Development of River Transportation." E. K. Morse, Consulting Engineer, Pittsburgh.

March 5—"Construction of Concrete Reservoirs, with Special Reference to Foundation Work in Abandoned Mines," R. M. Riegel, Departmental Designing Engineer, Department of Public Works, City of Pittsburgh, and G. L. Hendrickson, Designing Engineer, Bureau of Water, Department of Public Works, City of Pittsburgh.

May 7—"Highway Construction," Samuel Eckels, Chief Engineer, Department of Highways, Harrisburg, Pa.

November 15—"Recent Practice in Bridge Construction, with Special Reference to the Use of Higher Stresses," John L. Harrington, Harrington & Cortelyou, Consulting Engineers, 1004 Baltimore Ave., Kansas City, Mo. "Application of Soil Mechanics to Foundation Design," Dr. Glennon Gilboy, Assistant Professor of Soil Mechanics, Massachusetts Institute of Technology, Cambridge, Mass. "Bridge Architecture," Wilbur J. Watson, Engineer, Wilbur Watson and Associates, 4614 Prospect Ave., Cleveland, Ohio.

Respectfully submitted,

J. F. Laboon, *Chairman.*

REPORT OF ELECTRICAL SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

I wish to report on the work done by the Electrical Section during the year 1929, as follows:

Seven meetings were held during the year, with a total attendance of 3000, the maximum being 425 at the November 19th meeting, and the minimum at the December 12th meeting, with attendance of 140. A general discussion followed the presentation of all papers. The following papers were presented at meetings:

January 8—Mid-winter dinner meeting-student conference. "How the Institute Can Be of Greater Service," Prof. H. E. Dyche, University of Pittsburgh, Pittsburgh.

February 12—"The Extinction of an Alternating Current Arc." Joseph Slepian, Consulting Engineer, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

March 12—Annual meeting. "Long-Distance Toll Cable Transmission," J. A. Cadwallader, Engineer of Transmission and Outside Plant, Bell Telephone Co. of Pennsylvania, Pittsburgh.

April 13—Inspection trip to West Penn Power Co., Lake Lynn Hydro-Electric Generating Station, Lake Lynn, Pa.

May 21—Annual dinner and dance. "Miracles of Science," H. C. White, Edison Lamp Works, General Electric Co.

September 18—Inspection trip to Bell Telephone Equipment Building, 416 Seventh Ave., Pittsburgh.

October 15—"Making Sound Visible and Light Audible," John B. Taylor, Consulting Engineer, Central Station Department, General Electric Co., Schenectady, N. Y.

November 19—"What's Coming in Aviation," W. B. Stout, President, Stout Metal Airplane Co. Division, Ford Motor Co., Dearborn, Mich.

December 12—"'Latest Developments in Supervisory Control," R. J. Wensley, Westinghouse Electric & Manufacturing Co., Mansfield, Ohio.

Respectfully submitted,

J. I. Alexander, *Chairman.*

REPORT OF ILLUMINATING ENGINEERS' SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

The Illuminating Engineers' Section of this Society has the following report to make of the work done during the year 1929:

Four technical meetings of the Section were held jointly with the Pittsburgh Chapter of the Illuminating Engineering Society.

On January 21, John A. Hoeveler, Manager, Engineering Department, Pittsburgh Reflector Co., Pittsburgh, discussed the matter of "Mobile Color Lighting." The use of color, in particular changing color, in the show windows and on the exterior of buildings, is recognized as an advertising medium of great potentiality. The incandescent lamp, together with modern reflectors of the projector type and color filtering media, as well as the newly developed electrical control equipment, makes possible some remarkable achievements in the application of colored lighting.

On March 19, Dr. C. H. Robinsteen, of the Homeopathic Hospital, Pittsburgh, gave a paper on the subject, "Ultra-Violet Light." When it is realized

that people are denied the benefits of the healthful ultra-violet radiant energy received from the sun for a good many months during the winter, it will be appreciated that a study of artificial methods of supplying ultra-violet light and its value as a substitute for sunlight is a matter of wide-spread interest and very great importance to the maintenance of health.

On September 16, Mr. H. L. Johnsten, Director of Industrial and Commercial Lighting, Duquesne Light Co., Pittsburgh, gave a paper on the subject, "Light's Golden Jubilee." This was a timely paper, coming just one week before the nation-wide celebration of this epoch-making event, in which Pittsburgh participated on a magnificent scale.

On December 16, Mr. Frank K. Moss, Physicist, Lighting Research Laboratory, Nela Park, Cleveland, Ohio, gave a paper on the subject, "The New Science of Seeing." Seeing is the result of a partnership of lighting and vision. Extensive though incomplete knowledge is available pertaining to the eyes and to the visual sense. The optical profession deals with this partner which, by means of lenses, if necessary, is best fitted for its work. Lighting is a relatively new art in whose accomplishments the lighting profession can take justifiable pride. However, relatively little has been accomplished in the development of the partnership of lighting and vision which results in seeing. Since artificial light has become highly controllable in quality, quantity and distribution, we have the need of and opportunity to develop a new science, seeing. Mr. Moss presented systematized glimpses of the results of scientific investigation, aiming to show that this new science of seeing is in the making. Upon a foundation of this new science the seeing specialist has an opportunity to develop and to serve the work world, so that human beings may conserve and utilize their resources to the best advantage of themselves and of civilization.

Respectfully submitted,

JOHN A. HOEVELER, *Chairman.*

REPORT OF MECHANICAL SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

DEAR SIRS:

I wish to submit herewith report of the Mechanical Section of the work done during the year 1929, as follows:

Two meetings of the Section were held, one being the annual meeting and the other being an all-day conference, with an average attendance of 57 and a maximum attendance of 135, at the all-day conference on October 1. All meetings were held jointly with the Pittsburgh Section of the A. S. M. E. The following papers were presented:

February 14—Annual meeting. "Mechanical Equipment for the Davison Coke & Iron Co. at Neville Island," G. E. Dignan, Chief Engineer, Davison Coke & Iron Co., Neville Island, Pittsburgh.

October 1—All-day conference. "Industrial Power," J. H. Lawrence, President, Thomas E. Murray, Inc., 88 Lexington Ave., New York. "Industrial Power from the Executive's Standpoint," J. C. Hobbs, Superintendent of Power, Diamond Alkali Co., Painesville, Ohio. "Trend in Design and Operation of Industrial Plants, with Special Reference to Size of Furnaces," Henry Kreisinger, Combustion Engineering Corp., New York, N. Y. "Some Economic Fallacies on Isolated Plant Cost Analysis," F. M. Van Deventer, Mechanical Engineer, H. L. Doherty & Co., New York, N. Y.

Respectfully submitted,

CHAS. A. CARPENTER, *Chairman.*

REPORT OF MINING SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

DEAR SIRS:

I wish to submit herewith report of the Mining Section of the work done during the year 1929, as follows:

Three meetings of the Section were held, one being the annual meeting, one an all-day conference, and the other an evening meeting. There was an average attendance of 75, the maximum being at the all-day conference on November 26, with an attendance of 215, and the minimum at the annual meeting, February 25, with an attendance of 69. The average number discussing the papers was 15. The following papers were presented:

February 25—Annual meeting. "Oil Sand Mining as Practiced in France and Germany," George S. Rice, Chief Mining Engineer, U. S. Bureau of Mines, Washington, D. C.

October 7—Bi-monthly meeting. "The Coal Areas of Alaska and Western Canada," George Watkin Evans, Consulting Coal Mining Engineer, Seattle, Wash.

November 26—All-day conference. Papers were presented by the following: H. N. Eavenson, Consulting Engineer, Pittsburgh; M. D. Cooper, Division General Superintendent, Hillman Coal & Coke Co., Pittsburgh; H. E. Mason, Superintendent, H. C. Frick Coke Co., Pittsburgh; H. M. White, Manager of Mines, Pittsburgh Coal Co., Pittsburgh; J. C. White, Production Engineer, Pittsburgh Coal Co., Pittsburgh; E. J. Weimer, Superintendent, Butler Consolidated Coal Co., Butler, Pa.; L. H. Schnerr, Division Manager, The Consolidation Coal Co., Pennsylvania Division, Fairmont, W. Va.; E. A. Siemon, Division General Superintendent, Hillman Coal & Coke Co., Pittsburgh; G. B. Southward, Mechanization Engineer, The American Mining Congress, Washington, D. C.; T. F. McCarthy, Assistant General Superintendent, Clearfield Bituminous Coal Corp., Indiana, Pa.; Fred Norman, Chief Engineer, Allegheny River Mining Co., Kittanning, Pa.; J. A. Saxe, Chief Engineer, Ellsworth Collieries Co., Ellsworth, Pa.

Respectfully submitted,

L. E. YOUNG, *Chairman.*

REPORT OF STEEL WORKS SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

DEAR SIRS:

I wish to submit herewith report of the Steel Works Section of the work done during the year 1929, as follows:

Two meetings of the Section were held during the year, one being the annual meeting. The average attendance was 50, the maximum attendance 107, at the January 29 meeting, and the minimum, 35, at the all-day conference on October 28. The average number discussing the papers was 10. The following papers were presented:

January 29—Annual meeting. "Purchasing Public Utility Energy for Industrial Use," W. B. Skinkle, Engineer, Pittsburgh District Power Committee, Subsidiary Companies of U. S. Steel Corp., Pittsburgh.

October 28—All-day conference. "Steel-Plant Costs from the Standpoint of the Auditor," W. H. Dupka, Controller, Jones & Laughlin Steel Corp., Pittsburgh. "The Cost-Sheets and Their Relation to Engineering Economics,"

W. B. Skinkle, Engineer, Pittsburgh District Power Committee. "Steel-Plant Operating Budgets," L. C. Edgar, Chief Engineer, Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa.

Respectfully submitted,

B. R. SHOVER, *Chairman.*

REPORT OF TELLERS

To the Members of
Engineers' Society of Western Pennsylvania.

DEAR SIRS:

In accordance with Section IX, Article V, of the By-Laws of our Society, your tellers, appointed by the President, publicly canvassed the ballots in the election of officers at noon, Tuesday, January 14, 1930, and wish to report as follows:

Total ballots counted—463.

For President	W. L. Affelder	460
For Vice President	F. R. Phillips	459
For Treasurer	A. Stucki	462
For Directors	J. F. Laboon	457
	F. F. Schauer	459

Respectfully submitted,

WILLIAM SHAW, *Chairman,*
W. C. BUELL, JR.,
W. F. SANDVILLE,
Tellers.

The President thereupon declared the following gentlemen elected:

President	W. L. Affelder
Vice President	F. R. Phillips
Treasurer	A. Stucki
For Directors	J. F. Laboon
	F. F. Schauer

ANNUAL MEETING—CIVIL SECTION

January 7, 1930

The annual meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday evening, January 7, at 8:15 o'clock, Chairman J. F. Laboon presiding, 43 members and visitors being present.

The minutes of the last annual meeting, held January 8, 1929, were read and approved.

The report of the Nominating Committee was presented as follows:

Chairman	E. E. Lanpher
Vice Chairman	C. N. Haggart
Directors	L. B. Duff C. K. Harvey Jonathan Jones F. S. Merrill L. J. Riegler

Respectfully submitted,

R. P. Forsberg, *Chairman,*
C. S. Davis,
R. M. Riegel,
Nominating Committee.

On motion, nominations were closed and the Secretary was requested to cast a unanimous ballot for the nominees, who were thereupon declared elected.

Due to the absence of the Chairman-elect, Vice Chairman C. N. Haggart took the chair.

The address of the retiring Chairman, J. F. Laboon, on "Sewage Disposal and Garbage Incineration for Greenville, Pa." was then presented, and the ensuing discussion was participated in by the following:

R. G. Bauer, Koppers Bldg., Pittsburgh; L. P. Blum, Blum, Weldin & Co., Pittsburgh; C. N. Haggart, 335 Fifth Ave., Pittsburgh; V. R. Covell, 519 Smithfield St., Pittsburgh; J. F. Laboon, 813 Clark Bldg., Pittsburgh; P. J. Freeman, 519 Smithfield St., Pittsburgh; C. A. Keelan, 725 Grant Bldg., Pittsburgh; W. L. Keller, The Koppers Co., Pittsburgh; P. S. Wickerham, Butler, Pa.

The meeting adjourned at 10 P. M.

K. F. Treschow, *Secretary.*

ANNUAL MEETING—MINING SECTION

January 28, 1930

The annual meeting of the Mining Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday evening, January 28, at 8 o'clock, Chairman G. F. Osler presiding, 58 members and visitors being present.

The minutes of the last meeting, held February 25, 1929, were read and approved.

The report of the Nominating Committee was presented as follows:

To Members of Mining Section,
Engineers' Society of Western Pennsylvania.

DEAR SIRS:

In accordance with the By-Laws of the Section, your Nominating Committee, appointed by the Chairman, met January 23, and respectfully submits the following members as nominees for the offices of the Section for the coming year:

G. F. Osler.......................Chairman
J. F. Robinson.......................Vice Chairman
Directors....................... R. M. Black, Joseph Bryan, M. D. Cooper, T. B. Sturges, J. C. White

Respectfully submitted,

L. O. LOUGEE, *Chairman,*
C. E. LESHER,
W. E. FOHL,
Nominating Committee.

On motion, the nominations were closed and the Secretary instructed to cast a unanimous ballot for the officers named, who were thereupon declared elected.

No further business coming before the Section, the paper of the evening, on "Coal-Loading Machines and Their Development," was presented by the retiring Chairman, Mr. L. E. Young.

The following participated in the discussion: J. W. Paul, Mining Engineer, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh; E. A. Holbrook, Dean, School of Engineering, University of Pittsburgh, Pittsburgh; E. B. Gellatly, Proprietor, E. B. Gellatly & Co., Inc., Oliver Bldg., Pittsburgh; G. F. Osler, President, Chartiers Creek Coal Co., 218 Pike St., Canonsburg, Pa.; Arthur Neale, Mining Engineer, 198 West Prospect Ave., Crafton, Pa.; W. L. Affelder, Hillman Coal & Coke Co., Pittsburgh.

A vote of thanks was extended to Mr. Young for his interesting and instructive paper.

The meeting adjourned at 10:10 P. M.

K. F. TRESCHOW, *Secretary.*

ANNUAL MEETING—MECHANICAL SECTION

February 11, 1930

The annual meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held Tuesday evening, February 11, at 8:30 o'clock, in the Cardinal Room of the William Penn Hotel, Chairman C. A. Carpenter presiding, with 44 members and visitors being present.

The minutes of the last annual meeting, held February 14, 1929, were read and approved.

The report of the Nominating Committee was read by the Chairman, as follows:

To Members and Officers of Mechanical Section,
Engineers' Society of Western Pennsylvania.

DEAR SIRS:

In accordance with the By-Laws of the Section, your Nominating Committee, appointed by the Chairman, has met and submits the following members as nominees for the offices of the Section for the coming year:

Chairman .... W. P. Chandler, Jr.
Vice Chairman .... W. N. Flanagan
Directors .... R. N. Overton, T. E. Purcell, H. M. Hallett, R. E. Butler, J. F. Kroske

Respectfully submitted,

WILLIAM SHAW, *Chairman,*
R. E. BUTLER,
J. S. FULTON,
Nominating Committee.

On motion, the nominations were closed and the Secretary instructed to cast a unanimous ballot in favor of the officers named, who were thereupon declared elected.

Vice Chairman W. N. Flanagan then took the chair.

No further business coming before the Section, an address by the retiring Chairman, C. A. Carpenter, was presented, on "Application of Centrifugal Fans."

The ensuing discussion was participated in by the following: W. N. Flanagan, Special Engineer, Carnegie Steel Co., Pittsburgh; L. R. Robinson, Partner, Robinson Bros. Co., Zelienople, Pa.; R. R. Robinson, Partner, Robinson Bros. Co., Zelienople, Pa.; C. A. Carpenter, Hydraulic Press Mfg. Co., Mt. Gilead, Ohio; H. A. Lopez, Engineer, B. F. Sturtevant Co., Park Bldg., Pittsburgh; D. E. Cutler, Compressor Specialist, General Electric Co., Oliver Bldg., Pittsburgh; C. W. Daubert, Engineer, American Sheet & Tin Plate Co., Frick Bldg., Pittsburgh; J. F. Barnes, Assistant Secretary, Eljer Co., Ford City, Pa.; J. A. Graham, Superintendent Buildings and Grounds, Shady Side Academy, Aspinwall, Pittsburgh.

The meeting adjourned at 10:50 P. M.

K. F. TRESCHOW, *Secretary.*

ANNUAL MEETING
ILLUMINATING ENGINEERS' SECTION

February 17, 1930

The annual meeting of the Illuminating Engineers' Section was held in the Blue Room of the William Penn Hotel, Monday evening, February 17, at 8:30 o'clock, Mr. H. L. Johnston presiding, with 44 members and visitors being present.

The minutes of the last meeting, held March 19, 1929, were read and approved.

The annual report of the Section was presented by the Secretary.

The report of the Nominating Committee was presented as follows:

J. A. Hoeveler .... Chairman
J. S. Schuchert .... Vice Chairman
W. H. Horton, L. M. Riddle, J. P. Warner, H. L. Johnston, J. H. Van Es .... Directors

Respectfully submitted,

J. I. Alexander, *Chairman,*
F. W. Loomis,
E. S. Simons,
Nominating Committee.

On motion, duly seconded and carried, the nominations were closed and the Secretary instructed to cast a unanimous ballot of the members present in favor of the election of the gentlemen nominated, and they were therefore declared elected.

No further business coming before the meeting, the paper of the evening, on "Illumination for Sports," was presented by Mr. J. A. Summers, Edison Lamp Works, Engineering Department, Harrison, N. J. After a brief discussion of the paper, a vote of thanks was tendered the speaker for his very interesting paper.

The meeting adjourned at 10:45 P. M.

K. F. Treschow, *Secretary.*

ANNUAL MEETING—STEEL WORKS SECTION

February 25, 1930

The annual meeting of the Steel Works Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room of the William Penn Hotel, Tuesday evening, February 25, at 8 o'clock, Chairman B. R. Shover presiding, 48 members and guests being present.

The minutes of the last annual meeting, held January 29, 1929, were read and approved.

The annual report of the Chairman was submitted.

The report of the Nominating Committee was presented by the Secretary, as follows:

S. S. Wales ....Chairman
Lauson Stone ....Vice Chairman
Louis Ellman
C. W. Daubert
D. D. Pendleton } ....Directors
J. B. Wharton
William Whigham

Respectfully submitted,

W. B. Skinkle, *Chairman,*
G. D. Bradshaw,
D. A. Polhemus,
Nominating Committee.

On motion, the nominations were closed and the Secretary was instructed to cast a unanimous ballot for the officers named, and they were thereby declared elected. Chairman-elect S. S. Wales then took the chair.

No further business coming before the Section, the paper of the evening, on "Alloy Steels," was presented by Mr. E. C. Smith, of the Central Alloy Steel Corporation, Massillon, Ohio. Several participated in the discussion.

On motion, a vote of thanks was extended to Mr. Smith for his very interesting paper.

The meeting adjourned at 10:10 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION MEETING

February 18, 1930

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor D of the William Penn Hotel, Tuesday, February 18, at 12 o'clock, President W. L. Affelder presiding, Messrs. W. P. Chandler, Jr., A. S. Davison, J. A. Hunter, J. F. Laboon, C. E. Lesher, G. F. Osler, F. F. Schauer, B. R. Shover and W. B. Skinkle being present, Messrs. J. I. Alexander, J. N. Chester, L. C. Edgar, J. A. Hoeveler, T. J. McLoughlin, F. R. Phillips, G. F. Siefers and A. Stucki being absent.

The minutes of the last regular meeting, held January 14, were approved without reading.

Applications from the following gentlemen, having been published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Bingham, William Charles	Newlon, John Hawker
Judy, Edward W.	Osborne, Raymond Storms
Lytle, William Orland	Winslow, George W.

ASSOCIATE

Swem, George A.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Ferree, Jay W.	Ladd, Tallman
Fulton, Luther D.	Leerberg, Nis
Guibert, Oscar Eugene	Millar, Roger A.
Horton, W. H.	Mullin, John William
Hyland, C.	Webster, J. E.

Williams, Burdell Sanford

ASSOCIATE MEMBERS

Beymer, R. Alvin	Land, J. Stanley
Bott, Clarence C.	Longwill, Noble Clayton

ASSOCIATES

Davis, Ross Irwin	Nicol, George S.
Fawcett, William H.	Noble, Albert G.

Applications for transfer to a higher grade were received from the following, and after discussion it was moved and carried that they be transferred to full membership: C. B. Downer, Arthur Nuernberg and P. L. Weir.

An application for reinstatement was received from Mr. Sergius P. Grace, care Bell Telephone Laboratories, New York, and after discussion it was moved and carried that he be reinstated to membership.

The Secretary reported the following deaths:

Jo. P. Cappeau, Jr. (Assoc. Member), 1041 Kennedy Bldg., Tulsa, Okla. (Joined the Society January, 1925; died January 18, 1930.)

J. M. Hansen, 1120 Frick Bldg., Pittsburgh. (Joined the Society February, 1917; died December 13, 1929.)

E. E. Lanpher, Bureau of Water, City of Pittsburgh, Pittsburgh. (Joined the Society July, 1916; died January 18, 1930.)

Benjamin Thompson (Honorary Member), Tampa, Fla. (Joined the Society May, 1893; died February 5, 1930.)

The report of the Secretary, showing the condition of the finances at the close of business, January, 1930, having been audited by the Finance Committee, was approved.

In connection with the Secretary's report, the Chairman of the Finance Committee reported that the Finance Committee had been reorganized for the year and one meeting held, at which a budget of expenditures and receipts was prepared. The following appointments on the Committee were made: C. E. Lesher, Chairman, W. E. Fohl, G. E. Dignan and Louis Ellman. Mr. Lesher then presented the following estimated budget of expenditures and receipts, calling attention to the fact that in both cases the items were based on last year's report of actual expenditures and receipts. Only one change, concerning reduction of meeting expense from $2900 to $2400 has been made, inasmuch as last year's actual meeting expense was $2285, which included bills held over from the year 1928, amounting to about $800.

Provision has also been made for the amount of $5,280, covering refund for deficit incurred during the year 1929.

Recommendation has also been made by the Membership Committee that a card index of companies be made up for the purpose of assisting the Committee in their work of securing new members. The Secretary reported that this work would probably take two weeks to complete it.

Mr. Lesher called attention to the fact that it would be advisable to set aside $1,000, in addition to the above budget, which amount could be invested and used for emergency purposes, for such time as the year 1929, or some future year, when the receipts reached the point when they did not meet the expenditures. It was regularly moved and carried that the Finance Committee be authorized to set aside this amount.

The Membership Committee held one meeting to go over applications received since the last meeting of the Board and to act on any other business coming before the Committee.

The suggestion was made that engraved invitations be sent to the following: C. M. Yohe, Vice President, Pittsburgh & Lake Erie Railroad, P. & L. E. Terminal Bldg., Pittsburgh, and E. W. Smith, Vice President, Pennsylvania Railroad, Pennsylvania Station, Room 909, Pittsburgh. After discussion, it was moved and carried that the Secretary be instructed to send engraved invitations to the above gentlemen.

Mr. Affelder called attention to the possibility of securing new members from the attendance at the Annual Banquet, stating that he had gone over the seating list and found that quite a large percentage of the guests were non-members. He stated he had already secured three applications from this source and promised the Membership Committee to bring in ten additional members before the next meeting. The suggestion was made that possibly members of the Board could assist also by going over the seating list and writing to those with whom they are acquainted who are non-members. After a general discussion, the Secretary was requested to send the banquet seating list to each member of the Board of Direction, with the names of members checked.

Mr. A. S. Davison, Chairman of the Entertainment Committee, reported the appointment of the following men to serve on this Committee for the coming year, and stated that an organization meeting had been called for next week: J. I. Alexander, D. W. Allan, L. R. Botsai, Joseph Bryan, T. C. Clifford, H. W. Ewald, W. E. Homer, H. E. Passmore, Van A. Reed, Jr., J. F. Robinson, W. F. Sanville and W. B. Spellmire.

It was regularly moved and carried that the thanks of the Board of Direction be extended to the Entertainment Committee for the excellent work done in connection with the Annual Banquet of the Society.

The President announced that in accordance with action taken at the last meeting of the Board, the following Committee had been appointed to take charge of the program for our Fiftieth Anniversary Committee: George S. Davison, Chairman, J. A. Hunter, L. C. Edgar, V. R. Covell and F. F. Schauer.

The Special Committee composed of C. E. Lesher, A. S. Davison and the Secretary, which was appointed at the last meeting of the Board, presented the following amendment to the By-Laws, covering an increase in Life Membership:

> "Section V. A Member or Associate Member not in arrears, may, by the payment of $500.00 at any time, become a Life Member and, therefore, be relieved of the payment of annual dues."

After a general discussion, it was regularly moved and carried that the Secretary be authorized to place the matter before the membership by letter ballot, in accordance with the By-Laws.

The Secretary presented a letter, dated January 29, 1930, from Mr. L. W. Wallace, Executive Secretary, American Engineering Council, Washington, D. C., asking the Society to lend its support to the passing of Bills S. 3043 and H. R. 8299, authorizing the establishment of a National Hydraulic Research Laboratory in the Bureau of Standards. It was regularly moved and carried that this matter be tabled.

The Secretary presented a letter, dated February 10, 1930, from the Jail Removal Association, Pittsburgh, asking for an endorsement of their plan for a proposed public square on the site of the present jail. It was regularly moved and carried that this matter be tabled.

The Secretary presented the following letter, dated January 21, 1930, from Dean E. A. Holbrook, of the University of Pittsburgh:

> "Captain Harry W. Hill, of the Regular Army, is Executive Officer of the Pittsburgh Engineering Procurement District. Among his duties he has been requested by the War Department to organize in this district an Engineers' Advisory Committee, to be made up of executives of organizations in the Pittsburgh industrial district which have to do with power, communication, fuel and other engineering interests. He has asked that I assist him in the formation of this committee.
>
> We believe that the President of the Engineers' Society of Western Pennsylvania should be a member of this Committee. This of course would involve a new man from time to time as your Presidents change, but the Society would have in this way continued representation on the Committee.
>
> The duties of the Committee are at present nominal, but the War Department has asked for the formation of the Committee, so that in case of a national emergency they can have a selected list of executives in this district in the engineering procurement work on which they may call for advice and assistance.
>
> If your Board considers favorably this request, you will be notified formally later of your appointment."

After discussion, it was regularly moved and carried that the Secretary be authorized to notify Dean Holbrook that the Society would be very glad to be represented on this Committee.

The meeting adjourned at 2 P. M.

K. F. TRESCHOW, *Secretary.*

BOARD OF DIRECTION MEETING

March 18, 1930

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the King Albert Salon, William Penn Hotel, Tuesday, March 18th, at 12:00 o'clock, Mr. C. E. Lesher presiding in the absence of the President and Vice President, Messers. J. I. Alexander, W. P. Chandler, Jr., G. F. Osler, F. F. Schauer and W. B. Skinkle being present, Messrs. A. S. Davison, J. N. Chester, J. A. Hoeveler, J. A. Hunter, J. F. Laboon, T. J. McLoughlin, F. R. Phillips, G. F. Siefers, A. Stucki and S. S. Wales being absent.

The minutes of the last regular meeting, held February 18, were approved without reading.

Applications from the following gentlemen, having been published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Ferree, Jay W.
Fulton, Luther D.
Guibert, Oscar Eugene
Horton, W. H.
Hyland, C.
Ladd, Tallman
Leerberg, Nis
Millar, Roger A.
Mullin, John William
Smith, E. W.
Webster, J. E.
Williams, Burdell Sanford
Yohe, C. M.

ASSOCIATE MEMBERS

Beymer, R. Alvin
Bott, Clarence C.
Land, J. Stanley
Longwill, Noble Clayton

ASSOCIATES

Davis, Ross Irwin
Fawcett, William H.
Nicol, George S.
Noble, Albert G.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Behar, Manoel Felix
Cuthbert, William R. Jr.
Gott, Estep Tillard
Hooper, Arnold
Kutchka, Karl Gustav
Mitchell, H. L.
Moyer, F. Hughes
Peden, John T.
Thomas, P. C.
Williams, Emerson M.

ASSOCIATE MEMBERS

Butt, F. H.
Lee, A. A.
MacVean, Gordon
Sieffert, R. W.
Taylor, E. H.
Wakefield, H. E. Jr.

ASSOCIATES

Hanson, W. B.
Lyon, W. B.
Rupp, C. H.

JUNIOR

Tracy, S. J.

An application for transfer to a higher grade was received from Mr. W. H. McRoberts, Associate Member, 538 Dawson Avenue, Bellevue, Pa., and after discussion it was moved and carried that Mr. McRoberts be transferred to full membership.

The Secretary reported the following deaths:

J. E. Bigelow, 804 Union Bank, Pittsburgh, Pa.—Joined the Society, June, 1923. Died 1927.

J. H. Graybill, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.—Joined the Society, May, 1921. Died December 11, 1929.

J. M. Hansen, Standard Steel Car Co., Pittsburgh, Pa.—Joined the Society, February, 1917. Died December 14, 1929.

L. L. Satler, Jr., Allegheny Steel Co., Brackenridge, Pa.—Joined the Society, April, 1919. Died July 25, 1929.

M. S. Verner, Oakmont, Pa.—Joined the Society, May, 1865. Died March 21, 1929.

The report of the Secretary, showing the condition of the finances at the close of business, February 28, having been audited by the Finance Committee, was approved.

The Secretary reported an evening attendance of 200 during the month of February.

The Membership Committee held one meeting to go over applications received since the last meeting of the Board and to act on any other business coming before the committee.

It was suggested that an engraved invitation be sent to B. F. Jones, III, Secretary, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

The meeting adjourned at 2:00 P. M.

K. F. Treschow,
Secretary.

BOARD OF DIRECTION MEETING

April 15, 1930

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor "D," William Penn Hotel, Tuesday, April 15, at 12:00 o'clock, President W. L. Affelder presiding, Messrs. W. P. Chandler, Jr., W. H. Buente, A. S. Davison, J. F. Laboon, G. F. Osler, T. J. McLoughlin and S. S. Wales being present, Messrs. J. N. Chester, L. C. Edgar, J. A. Hunter, C. E. Lesher, F. R. Phillips, F. F. Schauer, W. B. Skinkle and A. Stucki being absent.

The minutes of the last regular meeting held March 18, were approved without reading.

Applications from the following gentlemen, having been published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Behar, Mancel Felix
Cuthbert, William R. Jr.
Gott, Estep Tillard
Kutchka, Karl Gustav
Mitchell, H. L.
Moyer, F. Hughes
Peden, John T.
Thomas, P. C.
Williams, Emerson M.

ASSOCIATE MEMBERS

Butt, F. H.
Hooper, Arnold
Lee, Albert A.
MacVean, Gordon
Sieffert, R. W.
Taylor, E. H.
Wakefield, H. E. Jr.

ASSOCIATES

Hanson, W. B.
Lyon, W. B.
Rupp, C. H.

JUNIOR

Tracy, S. J.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Beerbower, Ralph G.
Bixby, William Peet
Kaiser, George K.
Morrow, J. B.
Siemon, Edward A.

ASSOCIATE MEMBERS

Ferrabee, Francis Gilbert
Haddock, Daniel T.
Heinrichs, Frank Wheddon
Edmonds, John F., Jr.
Lail, George G.
Owen, Robert R.
Simpson, T. Leslie

ASSOCIATES

Ritchie, Julian
Royston, William Albert, Jr.

STUDENT JUNIOR

Boleky, E. J. Jr.

Applications for transfer to a higher grade were received from the following Associate Members, and after discussion it was moved and carried that they be transferred to full membership:

Pettay, George Theodore
Taber, George H. Jr.

An application for reinstatement was received from J. F. Hanst, c/o Ingersoll Rand Co., 11 Broadway, New York, and after discussion it was moved and carried that he be reinstated to membership.

Letters of resignation were received from the following, and after discussion they were ordered accepted:

Hutchison, G. H.
Irwin, R. L.
Duncan, J. McA.

The Secretary reported the death of L. J. Affelder, who joined the Society July, 1902. Died April 8, 1930.

The report of the Secretary, showing the condition of the finances at the close of business, March 31, having been audited by the Finance Committee, was approved.

The Secretary reported an evening attendance of 250 during the month of March.

The Membership Committee held one meeting to go over applications received since the last meeting of the Board and to act on any other business coming before the committee.

The Secretary presented a letter from the Pennsylvania State College, asking that we appoint delegates to attend the election of Trustees, in accordance with our usual custom. It was regularly moved and carried that the President be authorized to appoint such delegates.

The meeting adjourned at 1:45 P. M.

K. F. TRESCHOW,
Secretary.

STEEL WORKS SECTION

The regular bi-monthly meeting of the Steel Works Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Wednesday evening, April 23, T. J. McLoughlin presiding in the absence of the chairman, S. S. Wales, 77 members and visitors being present.

The reading of the minutes of last meeting was dispensed with.

No further business coming before the Section, the paper of the evening on "Open Hearth Combustion," was presented by W. P. Chandler, Jr., Chief Engineer, Furnace Division, Blaw-Knox Company, Pittsburgh, Pa.

The following participated in the discussion of Mr. Chandler's paper: J. S. Unger, Manager Research Bureau, Carnegie Steel Company, 1054 Frick Building Annex, Pittsburgh, Pa.; C. L. W. Trinks, Profeessor Mechanical Engrg., Carnegie Institute of Technology, Pittsburgh, Pa.; Walter de Fries, Chief Engineer, W. B. Pollock Co., East Federal St., Youngstown, Ohio; T. J. McLoughlin, Fuel Engineer, Carnegie Steel Company, Duquesne, Pa.; N. S. Powell, Supt. Open Hearth Dept., Carnegie Steel Company, Duquesne, Pa.; J. B. Crane, District Manager, Cumbustion Engineering Corporation, 1606 First National Bank Building, Pittsburgh, Pa.; W. N. Flanagan, Special Engineer, Carnegie Steel Company, Pittsburgh, Pa.; E. A. Brown, Assistant to Chief Engineers, Carnegie Steel Company, Homestead Works, Homestead, Pa.

A vote of thanks was extended to Mr. Chandler for his very interesting paper.

The meeting adjourned at 10:45 P. M.

K. F. TRESCHOW,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor E, seventeenth floor, William Penn Hotel, Tuesday, May 20, at 12 o'clock, President W. L. Affelder presiding, Messrs. J. N. Chester, W. H. Buente, A. S. Davison, L. C. Edgar, J. A. Hunter, J. F. Laboon, G. F. Osler, F. F. Schauer and S. S. Wales being present, Messrs. H. E. Dyche, C. N. Haggart, J. A. Hoeveler, W. P. Chandler, Jr., C. E. Lesher, F. R. Phillips, W. B. Skinkle and A. Stucki being absent.

The minutes of the last regular meeting, held April 15, were approved without reading.

Applications from the following gentlemen, having been published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Beerbower, Ralph G.
Bixby, William Peet
Kaiser, George K.
Morrow, J. B.
Siemon, Edward A.

ASSOCIATE MEMBERS

Edmonds, Jr., John F.
Ferrabee, Francis Gilbert
Haddock, Daniel T.
Heinrichs, Frank Wheddon
Lail, George G.
Owen, Robert R.
Simpson, T. Leslie

ASSOCIATES

Ritchie, Julian
Royston, Jr., William Albert

STUDENT JUNIOR

Boleky, Jr., E. J.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Atwood, William Bartlett
Critchfield, Charles Lee
Monroe, Robert A.
Pigott, R. J.
Schisano, Charles F.

ASSOCIATE MEMBERS

Ely, Fred W.
Ewald, Robert F.
Kennedy, W. R.

ASSOCIATES

Sykes, C. S.
Powers, P. H.

Letters of resignation were received from the following and, after discussion, they were ordered accepted: F. W. Bremmer, H. B. Douglas, C. G. Gerber, J. W. Hallock, W. W. Stevenson, A. J. Stewart and Albert Unrue.

The Secretary reported the death of H. L. Dixon, of the H. L. Dixon Company, Carnegie, Pa., who joined the Society in February, 1905, and died May 3, 1930.

The report of the Secretary, showing the condition of the finances at the close of business April 30, having been audited by the Finance Committee, was approved.

The Secretary reported an evening attendance of 150 during the month of April.

Mr. Schauer, Chairman of the House Committee, reported a few conferences had been held with various executives of the hotel regarding the refurnishing and redecorating of the clubroom. Mr. Andrews, manager of the hotel, stated that the work would be started in about two or three weeks.

Mr. Davison, Chairman of the Entertainment Committee, reported that due to the warm weather there was a very small attendance at the recent Bridge Party. Plans are under way for the Boat Excursion to be held Friday, June 20, and the Committee hopes that members of the Board will lend their assistance in bringing out a large attendance at this event.

The Committee has also arranged for the first Golf Tournament this season, which will be held at the Nemacolin Country Club, Tuesday, June 10.

Mr. Edgar, Chairman of the Publication Committee, reported that his Committee met and recommended another Lecture Course for the coming season.

The President reported that, in accordance with instructions received from the Board, he had appointed M. D. Cooper and L. E. Young to represent the Society for the election of trustees for the Pennsylvania State College, State College, Pa. A third representative will be appointed in the near future.

The meeting adjourned at 1:45 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

September 16, 1930

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor "C," seventeenth floor, William Penn Hotel, Tuesday, September 16, at 12:00 o'clock, Mr. L. C. Edgar presiding in the absence of President W. L. Affelder, G. F. Osler, F. F. Schauer and S. S. Wales being present, Messrs. W. P. Chandler, Jr., J. N. Chester, H. E. Dyche, J. A. Hoeveler, J. A. Hunter, J. F. Laboon, T. J. McLoughlin, F. R. Phillips, W. B. Skinkle and A. Stucki being absent.

The minutes of the last regular meeting, held June 16, were approved without reading.

Applications from the following gentlemen, having been published to the Society pursuant to the action of the Board, were elected to membership:

MEMBER

Colburn, George M.

ASSOCIATE

Oppenheimer, Oscar W.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Grant, Henry Lee, Jr.
Lundeen, Ernest F.
Nichols, John T. Noy
Noyes, M. E.

ASSOCIATE MEMBERS

Beirne, Henry
Conway, Leon Francis
Lloyd, Edward W.
Mills, G. G.
Sachs, W. A.
Tatom, D. E.
Whipple, T. T.

ASSOCIATE

Ow, Charles

JUNIOR

McKinnon, N. C.

Applications for transfer to a higher grade were received from the following, and after discussion it was moved and carried that they be transferred to grades as shown below:

Ellman, Louis (Associate Member to Member)
Overton, Ralph (Associate Member to Member)

Letters of resignation were received from the following and, after discussion, it was moved and carried that they be accepted, with regret:

Arrowsmith, J. O.
Barry, L. T.
Bathgate, O. H.
Beck, W. J.
Boyd, Marcus
Campbell, J. R.
Chesrown, Elias
Cooley, H. M.
Emtick, A. B.
Flanagan, G. E.
Haertlein, Albert
Jett, C. C.
Karn, F. S.
Kirk, D. M.
Marsh, B. W.
Morris, E. W.

The Secretary reported the following deaths:

McDonald, T. M.	Singer, G. H.
Rodd, Thomas	Walker, J. B.

The report of the Secretary, showing the condition of the finances at the close of business, August 31, having been audited by the Finance Committee, was approved.

Mr. F. F. Schauer, Chairman of the House Committee, reported an evening attendance of 200 during the months of July and August.

The Membership Committee held one meeting to go over applications received since the last meeting of the Board and to act on any other business coming before the committee.

The Secretary reported that plans for the Fiftieth Anniversary celebration were nearing completion, the principal difficulty being the securing of a speaker for the banquet. The committee has been obliged to consider a change in the date from October 16 to October 27, in view of the fact that the Lehigh University is celebrating a dedication ceremony at that time and the American Gas Association is also holding a meeting. It was felt that these two activities would take quite a few of our members from the city.

Mr. Edgar, Chairman of the Publication Committee, reported that the Lecture Course announcements for the coming year would be mailed to the membership within the next few days. The Chairman also asked for the co-operation of the Board in disposing of strip tickets and suggested that each member be sent ten tickets.

The Secretary presented a letter, dated August 13, from Mr. L. W. Wallace, Executive Secretary, American Engineering Council, requesting our Society to appoint a committee to assist in the study being made on Airport Drainage and Surfacing. After discussion, it was regularly moved and carried that the President be instructed to appoint a committee to carry on this work.

The Secretary presented a letter, dated July 3, from the American Engineering Council regarding Bill H. R. 10625, to amend the Act entitled "An Act to protect navigation from obstruction and injury by preventing the discharge of oil into the coastal navigable waters of the United States." The letter called attention to the fact that this amendment dealt mainly with the pollution of navigable waters and asked that our Society appoint a committee to study the amendment and recommend to Council whether or not they should take any action on the bill. It was regularly moved and carried that the President be authorized to appoint a Committee to report on this bill.

The Secretary presented the following letter, dated July 12, from Mr. W. A. Weldin, Chairman of the Committee of the Society, to assist the American Engineering Council in the distribution of Council's code of Standard Traffic Signs, Signals and Markings:

Board of Directors,
Engineers' Society of Western Penna.,
Pittsburgh, Pa.

GENTLEMEN:

Your committee appointed to co-operate with the American Engineering Council in the distribution of the Council's code of Standard Traffic Signs, Signals and Markings, begs to report progress.

We enclose a detailed report submitted to Secretary Wallace covering the state of our work.

We would direct your attention to the list of counties where we have not yet established any contacts, and would respectfully request any members of the Board who have correspondents in those counties to write them on this subject. We can supply as many copies of the code as can be used.

We attach a specimen letter which sets forth the object and method of approach.

Your chairman attended the Third National Conference on Highway Safety in Washington on invitation of Secretary of Commerce Lamont, and as a delegate of the Engineering Council. He learned that gratifying progress has been made in the adoption of the code throughout the country, and that it is considered an important part of the work of the Conference which also covers uniform legislation and various safety measures.

Respectfully submitted,

(Signed) W. A. WELDIN, *Chairman.*

CIVIL SECTION

November 3, 1930

The regular bi-monthly meeting of the Civil Section of the Engineers' Society of Western Pennsylvania, was held Monday evening, November 3, in the Cardinal Room, William Penn Hotel, Chairman C. N. Haggart presiding, 285 members and guests being present.

The minutes of the last meeting held April 17, 1930, were not read.

As there was no regular business coming before the Section, Mr. J. W. Rickey, Chief Hydraulic Engineer, Aluminum Company of America, Pittsburgh, presented a paper on "The Chute a Caron Hydro-Electric Development on the Saguenay River, Province of Quebec, Canada. This paper was illustrated with slides and a motion picture film entitled "Tipping of the Chute a Caron Obelisk." The following participated in the discussion:

J. S. Jenks, Civil Engineer, West Penn Power Co., Pittsburgh, Pa.; P. J. Freeman, Chief Engineer, Bureau Tests and Specifications, Allegheny County, 519 Smithfield Street, Pittsburgh, Pa.; J. P. Growden, Hydraulic Engineer, Aluminum Company of America, Pittsburgh, Pa.; Fred Waldorf, Dist. Mgr. Steel Mill Div., Timken Roller Bearning Co., Pittsburgh, Pa.; Mr. Bleifus, Engineer, Aluminum Company of America, Pittsburgh, Pa.; Prof. Thomas, Prof. of Hydraulics, Carnegie Institute of Technology, Pittsburgh, Pa.

A rising vote of thanks was extended to Mr. Rickey for his extremely interesting paper.

The meeting adjourned at 10:20 P. M.

Respectfully submitted,

K. F. TRESCHOW, *Secretary.*

JOINT MEETING

Electrical Section of the Engineers' Society of Western Pennsylvania and Pittsburgh Section of the American Institute of Electrical Engineers

December 9, 1930

The regular monthly meeting of the Electrical Section of the Engineers' Society of Western Pennsylvania was held jointly with the Pittsburgh Section of the American Institute of Electrical Engineers in the Chamber of Commerce Auditorium, Tuesday, December 9, Chairman C. T. Sinclair presiding, 375 members and guests being present.

The minutes of the last meeting, held May 13, were dispensed with.

G. S. Merrill, General Electric Company, Nela Park, Cleveland, presented a paper on "Proper Voltage and Lighting Service," and a paper on "Artificial Sunlight" was presented by Dr. M. Luckiesch, Director Lighting Research Laboratory, Nela Park, Cleveland, Ohio. A vote of thanks was extended to both of these gentlemen for their very interesting addresses.

An interesting talking picture on "Dynamic America" was shown the earlier part of the evening.

On motion, duly seconded and carried, the meeting adjourned at 10:45 P. M.

K. F. TRESCHOW, *Secretary.*

BOARD OF DIRECTION

October 21, 1930

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor D, William Penn Hotel, Tuesday, October 21, W. L. Affelder presiding, Messrs. W. H. Buente, J. N. Chester, A. S. Davison, L. C. Edgar, C. N. Haggart, J. A. Hoeveler, J. A. Hunter, J. F. Laboon, C. E. Lesher, G. F. Osler, F. R. Phillips and W. B. Skinkle being present, Messrs. W. P. Chandler, Jr., H. E. Dyche, T. J. McLoughlin, F. F. Schauer, A. Stucki and S. S. Wales being absent.

The minutes of the last regular meeting, held September 16, were approved without reading.

Applications from the following gentlemen, having been published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Grant, Henry Lee, Jr.
Lundeen, Ernest F.
Nichols, John T.
Noyes, M. E.

ASSOCIATE MEMBERS

Beirne, Henry
Conway, Leon Francis
Lloyd, Edward W.
Mills, G. G.
Sachs, William Albert
Tatom, Dan Evans
Whipple, Thomas T.

ASSOCIATE

Ow, Charles

JUNIOR

McKinnon, Norman Charles

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Corbett, William J.
Rawstorne, C. D.
von Bernewitz, M. W.

ASSOCIATE MEMBER

Kuhl, E. W.

An application for transfer to a higher grade was received from R. T. Middleton and, after discussion, it was moved and carried that he be transferred to grade of Member.

Letters of resignation were received from the following and, after discussion, it was moved and carried that they be accepted with regret:

Allen, J. G.
Clyde, W. G.
Clark, D. G.
Denison, P. N.
Guy, F. W.
Horner, R. B.
Jackman, D. E.
Jones, Archibald
Oursler, J. S.
McElheny, G. S.
White, H. E.

Dropped from the rolls: J S. Hurn.

The Secretary reported the following death: H. L. Turner, Aluminum Company of America. Mr. Turner joined the Society January 15, 1930; died September 13, 1930.

The report of the Secretary, showing the condition of the finances at the close of business October 31, having been audited by the Finance Committee, was approved.

The Secretary, in the absence of Mr. Schauer, Chairman of the House Committee, reported an evening attendance of 200 during the month of September.

The Membership Committee held one meeting to go over applications received since the last meeting of the Board and to act on any other business coming before the committee.

Mr. Davison, Chairman of the Entertainment Committee, reported that a very successful Golf Tournament had been held September 22 at the South Hills Country Club, with an attendance of 110.

The Secretary, on behalf of G. S. Davison, Chairman of the Special Committee in charge of our Fiftieth Anniversary Celebration, stated that in accordance with the letter sent to the membership, the final date had been set for Friday, November 14. Detailed announcement will be mailed to the membership the latter part of this week and the committee hopes the members of the Board will make an effort to stimulate interest among the members to attend this celebration.

Mr. Edgar, Chairman of the Publication Committee, reported that the first lecture would be held Wednesday, October 22, and that returns to date indicated a much better sale of tickets than in previous years.

Mr. Hoeveler, Chairman of the Illuminating Engineers' Section, reported that the Illuminating Engineering Society had been invited to hold their 1931 meeting in Pittsburgh and suggested that the Board instruct the Secretary to write, on their behalf, endorsing this invitation. It was also suggested that the Society have a small card printed, which should be placed in the mail boxes of the visitors for these conventions, this to be done also when other organizations meet in Pittsburgh, thereby extending a welcome and inviting them to make use of our facilities during their stay in the city. This has been done in a number of cities and it is very much appreciated. Mr.

Chester stated that the American Water Works Association is to hold their annual meeting in Pittsburgh next year and suggested that a similar letter be sent to the American Water Works Association.

The attention of the Board was called to the generosity of A. S. Davison for the presentation of a very attractive trophy for the Golf Tournament of the Society. It was unanimously moved and carried that a letter of appreciation be sent to Mr. Davison, thanking him for his interest in presenting this trophy.

L. C. Edgar suggested that an engraved invitation be sent to R. W. Watson, Vice President, Carnegie Steel Company, Pittsburgh, Pa., and it was regularly moved and carried that the Secretary be instructed to send an invitation to Mr. Watson.

The meeting adjourned at 1:45 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

November 18, 1930

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor G, William Penn Hotel, Tuesday, November 18, President W. L. Affelder presiding, Messrs. J. N. Chester, A. S. Davison, J. A. Hunter, J. F. Laboon, C. E. Lesher, G. F. Osler, F. F. Schauer, W. B. Skinkle, S. S. Wales and T. J. McLoughlin being present, Messrs. W. H. Buente, W. P. Chandler, L. C. Edgar, C. N. Haggart, J. A. Hoeveler, H. E. Dyche, Norman Allderdice, F. R. Phillips and A. Stucki being absent.

The minutes of the last regular meeting, held October 21, were approved without reading.

Applications from the following gentlemen, having been published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Corbett, William J. Rawstorne, C. D.
von Bernewitz, M. W.

ASSOCIATE MEMBER

Kuhl, E. W.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Focer, P. C. Rinearson, R. W.

ASSOCIATE MEMBER

McCullough, W. T., Jr.

ASSOCIATE

Coxe, E. H., Jr.

Application for transfer to a higher grade was received from G. G. Mills and, after discussion, it was moved and carried that he be transferred to grade of Member.

An application for reinstatement was received from R. E. Walters, 607 Mechanics Building, Harrisburg, Pa., and, after discussion, it was moved and carried that he be reinstated to membership in the Society.

Letters of resignation were received from the following and, after discussion, it was moved and carried that they be accepted with regret:

Baker, David	Crocker, E. E.
Cowin, S. H.	Gerber, Carl B.
Emory, G. W.	Harris, Benjamin F.
Fleming, Thomas, Jr.	Holliday, A. H.
Gamble, E. E.	Smerling, Carl

Wolfe, Harry C.

The Secretary reported the following deaths: J. L. Klindworth, Jones & Laughlin Steel Corporation, Woodlawn, Pa.; died November 10, 1930. William Smith, 316 Monongahela Avenue, McKeesport, Pa.; died November 10, 1930. A. W. Thompson, 1225 Broad Street, Philadelphia, Pa.; died November 9, 1930.

The report of the Secretary, showing the condition of the finances at the close of business, October 31, having been audited by the Finance Committee, was approved.

The Membership Committee held one meeting to go over applications received since the last meeting of the Board and to act on any other business coming before the committee.

The Secretary reported on behalf of the Entertainment Committee to the effect that the committee was making preliminary arrangements for the Annual Dinner, but had nothing definite to report at the meeting.

Attention was called to the very successful party held in connection with our Fiftieth Anniversary, and it was moved and carried unanimously that the Secretary be instructed to write a letter, expressing the appreciation of the Board of Direction to the Fiftieth Anniversary committees for the very efficient manner in which this meeting was conducted.

In accordance with Section V, Article V, of the By-Laws, the following report was presented by the Nominating Committee:

President	L. C. Edgar
Vice President	A. S. Davison
Treasurer	A. Stucki
Directors	G. E. Stoltz G. F. Osler

Respectfully submitted,

RICHARD KHUEN, JR., *Chairman,*
J. I. ALEXANDER,
G. H. DANFORTH,
F. F. SCHAUER,
L. E. YOUNG,
Nominating Committee.

The meeting adjourned at 1:30 P. M.

K. F. TRESCHOW, *Secretary.*

BOARD OF DIRECTION

December 16, 1930

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor G, William Penn Hotel, Tuesday, December 16, at 12:00 o'clock, President W. L. Affelder presiding, Messrs. W. H. Buente, J. N. Chester, A. S. Davison, L. C. Edgar, C. S. Haggart, J. A. Hunter, J. F. Laboon, G. F. Osler, W. B. Skinkle and S. S. Wales

being present, and Messrs. N. Allderdice, W. P. Chandler, Jr., H. E. Dyche, C. E. Lesher, J. A. Hoeveler, T. J. McLoughlin, F. R. Phillips and A. Stucki being absent.

The minutes of the last regular meeting, held November 18, were approved without reading.

Applications from the following gentlemen, having been published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Focer, P. C.	Rinearson, R. W.

ASSOCIATE MEMBER

McCullough, W. T., Jr.

ASSOCIATE

Coxe, E. H., Jr.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Crawford, G. H.	Philp, B. K.
Mille, J. M.	Walters, J. B.

ASSOCIATE MEMBER

Nock, J. A.

ASSOCIATE

Elliott, H. L.

An application for reinstatement was received from Benjamin F. Harris and, after discussion, it was moved and carried that he be reinstated to membership in the Society.

Letters of resignation were received from the following and, after discussion, it was moved and carried that they be accepted with regret:

Bain, G. F.	Mattingley, G. B.
Hezlep, J. H.	Reno, E. S.

The Secretary reported the following death: I. W. Frank, 2301 Farmers Bank Building, Pittsburgh, Pa. Joined the Society, February, 1882; died December 1, 1930.

The report of the Secretary, showing the condition of the finances at the close of business, November 30, having been audited by the Finance Committee, was approved.

The Membership Committee held one meeting to go over applications received since the last meeting of the Board and to act on any other business coming before the committee.

Mr. Edgar, Chairman of the Publication Committee, reported that the committee expressed disappointment in the sale of lecture course tickets this year and urged the members of the Board to co-operate in the sale of tickets by bringing these lectures to the attention of their friends. A discussion then followed as to the advisability of continuing the lectures. It was suggested that unless the membership responds more enthusiastically than they have this year it might be best for the committee to discontinue them and have some other form of meeting. Mr. Edgar stated that the committee proposes to pass out a questionnaire at the February lecture, requesting those present to express their opinions regarding the lectures presented in the past and whether or not they desire them to be continued.

Mr. Davison, Chairman of the Entertainment Committee, reported that the committee had been very fortunate in securing Gerard Swope, President of the General Electric Company, New York, as principal speaker at the Annual Dinner, but in order to set a suitable date the committee was compelled to schedule the banquet February 26, rather than the latter part of January, as has been the custom in the past. The other speaker and toastmaster have not as yet been selected.

In accordance with Article V, Section V, of the By-Laws, the Board of Direction finally approved the names of the nominees as presented by the Nominating Committee at the November meeting of the Board, as follows:

President	L. C. Edgar
Vice President	A. S. Davison
Treasurer	A. Stucki
Directors	G. E. Stoltz G. F. Osler

Respectfully submitted,

Richard Khuen, Jr., *Chairman,*
J. I. Alexander,
G. H. Danforth,
F. F. Schauer,
L. E. Young,
Nominating Committee.

It was regularly moved and carried that the report be approved and published to the Society in accordance with the By-Laws.

The Secretary presented a letter from the Civic Club of Philadelphia regarding the pollution of the water in the streams of Pennsylvania and, after discussion, it was ordered tabled.

The Secretary also presented a letter from the National Association of Highway Officials, thanking our Society for the part taken in their recent convention held in Pittsburgh.

In accordance with the By-Laws of the Society, the Secretary presented a report of the Nominating Committee for Officers of the Society for the ensuing year. It was regularly moved and carried that the names be finally approved and the Secretary instructed to have the ballots printed and sent to the membership January 1.

The meeting adjourned at 1:45 P. M.

K. F. Treschow, *Secretary.*

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